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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 5.00	Members	$ 5.00
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This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England and one, the annual convention, held in September on such date as the Executive Committee may designate.

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	1931	11.9 miles 48",	51"
	1932	5.5 miles 30",	34", 42"
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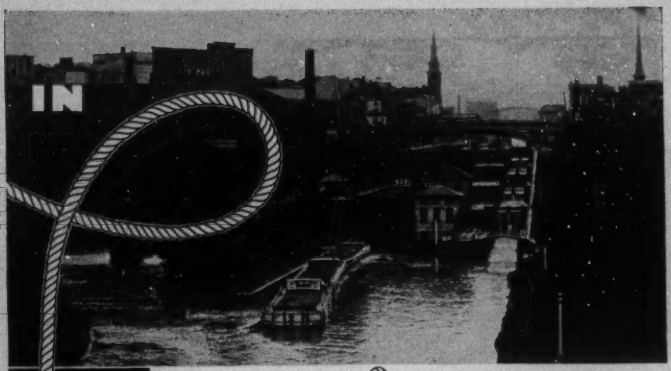

Lockport

NEW YORK

The City of Lockport, the County Seat of Niagara County, owes its origin, development and supremacy to its geological and geographical locations and the quality of its environment. The city is situated at a point where a high ridge forms a geological obstruction in the course of the Erie Canal causing a drop of 238 feet between the Erie and Ontario levels. Occupying a Key Position in the expansive area of the Niagara Frontier, the advantages of Lockport's location and her environment are closely interlinked. Sweeping away from the city in all directions is an agricultural district whose productiveness has established for it an international fame, as "The $10,000,000 Fruit Belt."

Lockport is essentially a manufacturing city and is the home of numerous industries whose products command the highest respect and which have a nation-wide distribution.

Lockport's new Filtration Plant, installed at a cost of $880,000, supplies the city with a bountsous flow of crystalline, pure water and has had a most beneficial effect on the health and vitality of the community. From the Niagara River at a point near LaSalle, a distance of 13 miles, the water is piped through thirty-inch steel force mains to the Filtration Plant which has a capacity of 12,000,000 gallons per twenty-four hours.

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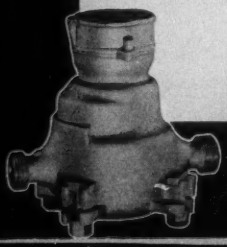

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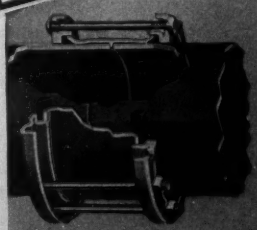

Cutaway view of Dresser Style 38 Coupling, showing working principle. Note that plain-end pipe is used. The resilient gasket, flexing with the pipe, safely absorb pipe movements.

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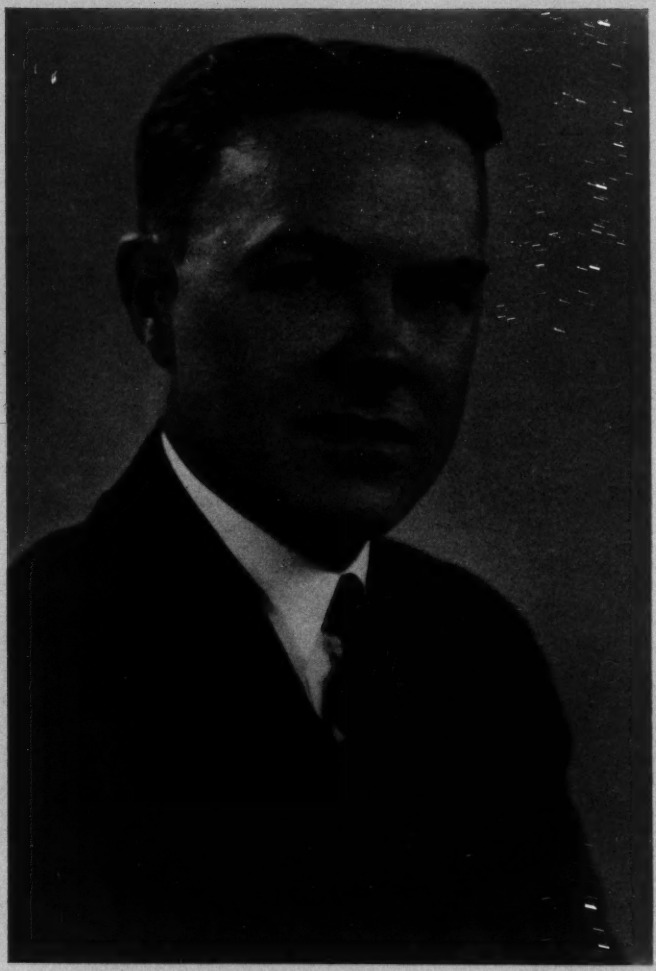

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WARREN J. SCOTT
President of the New England Water Works Association
1937-1938

New England Water Works Association
ORGANIZED 1882

Vol. LII March, 1938 No. 1

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PREPARING AND PACKAGING LIQUID CHLORINE AND ALLIED PRODUCTS FOR WATER PLANTS.

BY L. L. HEDGEPETH*

[Read November 18, 1937.]

A water plant receives a shipment of cylinders; valve hoods and caps are removed, the chlorinator is connected, and 750 cu. ft. of chlorine gas in each cylinder are on tap for their conditioning and germ-killing function in water purification. A tank car is spotted alongside an industrial plant, derails thrown and locked, warning signs placed, dome seal broken, lid thrown back, liquid valve connected to the receiving line, and 60,000 lbs. of chlorine in one vessel are on tap for processing purposes, 300,000 cu. ft. of gas compressed into a liquid state in a car having an internal volume of only 768 cu. ft., about one quarter of one per cent. of the gas volume.

Truly a modern miracle, this availability of chlorine in a highly condensed, completely available form and one as worthy of comment as radio, color-films, television, or the many other technical achievements so highly publicized. Surely this useful servant of civilization deserves more than passing attention from its most important consumers, the water purification technicians, and it is hoped that they will find interesting this portrayal of the preparation of chlorine, beginning with an electrical divorce from its "since the beginning of time" mate—sodium—followed by its purging, safe incarceration in a steel prison, and its hectic dissipation after release. The ultimate fate of its associate, sodium, and the hydrogen liberated from the electrically pulled apart water may also be of interest.

In selecting the material presented in this paper, considerable matter essential to a complete manufacturing discussion has been omitted as being of insufficient interest. A picture not too involved has been the goal.

Chlorine and its allied products are substances of substantial economic importance. The demands of United States industry and public health have been steadily increasing from a modest beginning

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in 1895[1] to a conservative estimate of 424,000 tons in 1936.[2] Chlorine was first shipped in its elementary form to consumers in 1909, being transported prior to that time as chlorinated lime, a loosely bound combination of chlorine and quick lime of the typical composition, $CaCl.OCl.H_2O$ with $CaO.CaCl.OCl.H_2O$ in variable proportions.

Chloride of lime has suffered a steadily declining market due to its higher delivery costs as well as its instability. It is no longer an important article of chemical commerce, being replaced almost entirely with liquid chlorine among the larger users, or the stable hypochlorites among the smaller consumers.

The chlorine industry plays an important part in our modern life. Soap, textile, paper, steel, power, chemical, and many other essential plants are its largest customers. Its major product, chlorine, is indispensable to public health protection.

The principal needs of the chlorine industry are common salt, electricity, and water. For each 100 lbs. of NaCl decomposed,[3] a typical plant delivers 60.7 lbs. chlorine, 68.4 lbs. caustic soda, and 1.7 lbs. hydrogen, requiring 82.2 kw-hr. power input to the cells. Substantial quantities of the chlorine and caustic and all of the hydrogen are used for processing other products in the plant. The captive chlorine is used for production of calcium hypochlorite, sodium hypochlorite, ferric chloride, muriatic acid, carbon tetrachloride and other chlorinated hydrocarbons. It is estimated that for the entire United States 275,600 tons of liquid chlorine were shipped to customers in 1936 and 148,400 tons were used on the producers' premises.

Manufacture in a Typical Plant

Since chlorine is never found free in nature, it must always be separated from one of its compounds. Common salt (NaCl) is generally used, although potassium chloride (KCl) is employed by some manufacturers in order to obtain caustic potash (KOH). Salt is removed from strata 1200 ft. deep, directly under the works (Fig. 1). Water is pumped into the salt deposit, forcing therefrom brine to the surface where it is purified and passed directly into the plant. A typical analysis of this brine is:[4]

	Per cent
Sodium chloride ($NaCl$)	25.23
Calcium sulphate ($CaSO_4$)	0.48
Calcium chloride ($CaCl_2$)	0.04
Magnesium chloride ($MgCl_2$)	0.04

Electricity, the decomposing force, is generated in a coal-fired power unit, the exhaust steam of which is utilized to evaporate water from dilute caustic soda liquors and for other process purposes (Fig. 2). Alternating current is first produced in multi-stage turbines and that

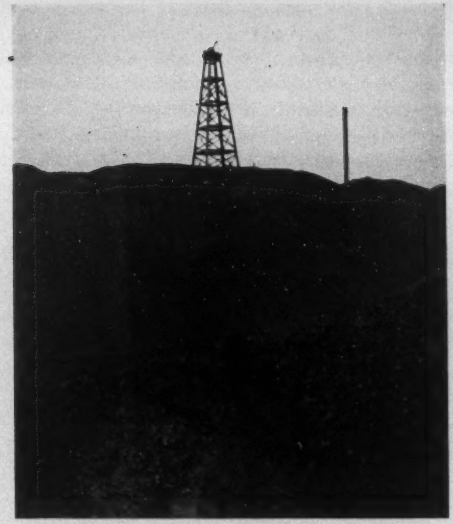


FIG. 1.—MATERIALS. SALT WELLS AND COAL PILES ARE THE RESERVE SUPPLY OF A CHLORINE PLANT.

FIG. 2.—POWER. MANY UNITS LIKE THIS ARE REQUIRED ELECTRICALLY TO DIVORCE CHLORINE AND CAUSTIC.

portion of it needed for decomposition of the salt is converted into direct current in rotary converters.

Soda ash for brine purification and concentrated sulphuric acid for chlorine gas drying are needed for processing. The sodium from the brine purification is retained in the brine and the diluted acid is used for other processing operations requiring sulphuric acid, or resold to users of this now less concentrated acid.

The flow of salt and water through electrolysis and subsequent

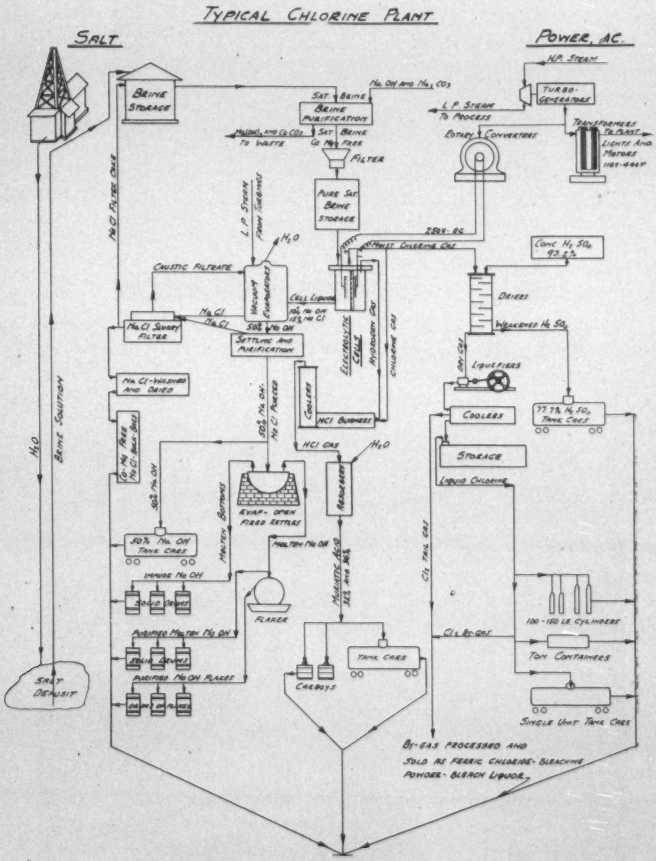


FIG. 3.—FLOW SHEET OF TYPICAL CHLORINE PLANT.

treatment, emerging finally as liquid chlorine, caustic soda, hydrogen, and combined products is depicted in Figure 3.

Brine purification consists of removing therefrom the small content of calcium and magnesium which would cause trouble in the cells. It is accomplished by precipating the calcium with soda ash and the magnesium with caustic soda. The precipitates are removed by sedimentation and filtration. The quantity of precipitants varies with the brine and is, therefore, difficult to estimate.[5] A fair average would be 2.61 lb. soda and 0.19 lb. caustic soda per 100 lb. sodium chloride yield from the purification tanks.

Dissociation of Sodium Chloride. The purified strong brine containing 25% NaCl is fed continuously into a battery of Gibbs's Cells where the following reaction takes place: Salt (NaCl) + Water (H_2O) + Electricity = Chlorine (Cl) + Caustic Soda (NaOH) + Hydrogen (H).

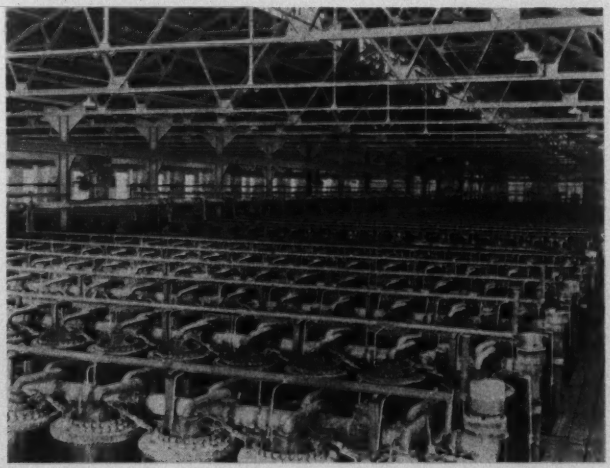


FIG. 4.—THE PLANT'S HEART. GIBBS' CELLS, ROW ON ROW—EACH DISCHARGING CHLORINE, HYDROGEN, AND CAUSTIC INTO SEPARATE HEADERS. HEAVY CURRENTS (1000 AMP. AT TIMES) ARE PASSED THROUGH THESE UNITS.

The elements of this unit are two electrodes of opposite electric charges separated by a diaphragm and immersed in a salt solution with direct current electricity flowing between them. The chlorine is attracted to and discharged as a gas at the anode (positive electrode), and the sodium is attracted to and discharged at the cathode (negative electrode), where it immediately reacts with water forming caustic soda and hydrogen gas (Fig. 4).

Twenty-four anodes, each 2 in. by 2 in. by 36 in., are used in each cell. Being made of graphite and not readily attacked by chlorine,

they have an average life of 600 days. A high current density (0.17 amp. per sq. in.)[6] is maintained on these anodes while they are in service. The cathode is a cylindrical perforated steel plate which is also not seriously attacked by caustic because it is electrically protected. A somewhat higher current density (0.27 amp. per sq. in.)[7] is maintained on the cathode. The cell can be operated continuously for 120 days before being taken out of service and rebuilt with new diaphragms.

Recombination of the caustic and chlorine is prevented by placing the anode and cathode on opposite sides of an asbestos diaphragm which permits free passage of the salt solution but effectively separates the caustic soda and hydrogen compartment from the chlorine.

The chlorine discharged on the surface of the anode appears in small bubbles which grow in size until they break away, rise to the surface of the brine and are drawn from the cells through acid-proof ceramic lines.

Drying Chlorine. Freshly formed chlorine picks up moisture while bubbling through the brine and consequently becomes very corrosive. Also present in measurable quantities are carbon dioxide, hydrogen, nitrogen, and oxygen. A typical analysis of the cell gas is:[8]

	Per cent.
Chlorine (Cl_2)	96.0 to 97.0
Carbon dioxide (CO_2)	1.0 to 2.0
Hydrogen (H_2)	0.1 to 0.2
Nitrogen (N_2)	1.2 to 1.3
Oxygen (O_2)	0.7 to 0.8
Water (H_2O)	Saturated vapor

Before further processing it is necessary completely to remove the moisture in order to handle and package the chlorine economically for market. This is readily accomplished by causing it to flow counter current through cascading strong sulphuric acid which dehydrates the chlorine gas. The dry chlorine issuing from these towers is noncorrosive to ordinary metals at normal temperatures.

Sulphuric acid is put in the driers at 66° Beaumé (93.2% H_2SO_4) and, because of its thirst for water, absorbs all of the water in the moist chlorine gas, leaving it anhydrous. Since the acid-handling equipment is made of steel, the acid[9] is withdrawn just before it becomes sufficiently dilute to attack iron. This concentration has been fixed at 60° Beaumé (77.7% H_2SO_4) for safety's sake, and the acid is withdrawn at this strength and further used as previously described.

Liquefying Chlorine. The next step leading to the production of liquid chlorine is the compression of the dried gas. An important

reason for the availability of chlorine to users at a reasonable price is its adaptability to a highly concentrated form of storage. A weight of 150 lbs. of liquid chlorine, for instance, varying in volume from 1.58 cu. ft. at 0°F. to 1.68 cu. ft. at 110°F., is safely stored and shipped in an economical steel container having an internal volume of only 1.92 cu. ft. Yet this quantity of chlorine readily expands to 500 cu. ft. or more, depending on its temperature when released. This compression[10] of the chlorine gas is conducted at 25 lbs. per sq. in. gauge pressure, requiring the use of large capacity low pressure blowers (Fig. 5). This

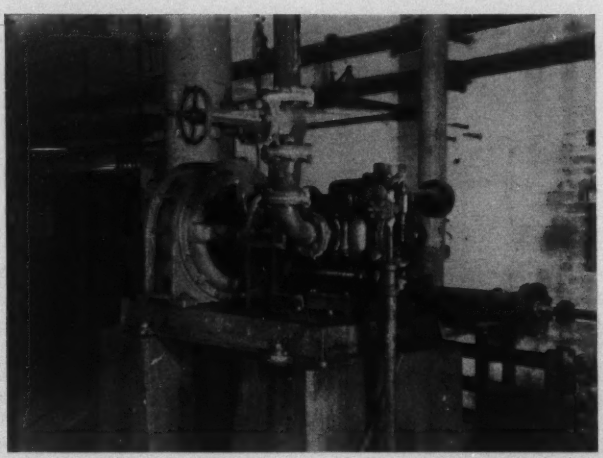


FIG. 5.—COMPRESSION OF CHLORINE. HIGH SPEED CENTRIFUGAL BLOWERS, SEALED WITH CONCENTRATED SULPHURIC ACID, ARE USED TO COMPRESS THE CHLORINE PRELIMINARY TO LIQUEFACTION.

low-pressure operation is quite feasible because at low temperatures chlorine has a correspondingly low vapor pressure and the gas is easily condensed by cooling below its pressure-temperature value for the prevailing pressures. The pressure-temperature behavior of liquid chlorine is shown in Figure 6. Cooling of the chlorine gas is accomplished in a direct system of refrigeration with a refrigerant having no affinity for chlorine (Fig. 7). The substance usually used is carbon dioxide.

At the depressed temperatures prevailing in the liquefiers, the compressed chlorine starts condensing and flows by gravity into storage tanks. When the concentration of chlorine gas drops to 50%,[11] it is no longer economical to liquefy it and, therefore, it is blown over to the several other processes in the plant using captive chlorine.

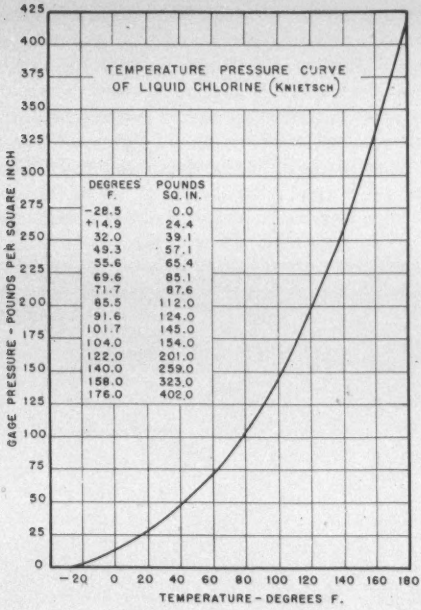


FIG. 6.

"Taffy" Removal. Marketable chlorine, intended for use through gas dispensing apparatus, must be purged of its wax-forming impurities if pleasant buyer-seller relations are to be maintained. This is accomplished in a fractionating column in which the dried cell gas from the blowers is washed with a small quantity of liquid chlorine. In its descent through the column the liquid chlorine absorbs the impurities from the gas stream, and an impure liquid chlorine collects at the base of the column, from which chlorine gas is driven off by application of heat. Purified gaseous chlorine flows from this unit to the liquefiers, leaving the organic impurities in liquid form at the base of the column from which they are periodically blown to waste. These impurities originate during contact between the chlorine and materials necessary for use in its preparation. These include packing, lubricants, resinous sealing compounds for cells and joints, and the binder for the dense graphite anodes.

In our work in this connection we have found that ferric chloride, hexachloroethane, carbon tetrachloride, bromine and chloroform comprise the bulk of the usual mass found. The solid hexachloroethane and ferric chloride will under some conditions be carried over with the gas

FIG. 7.—LIQUEFACTION OF CHLORINE AT DEPRESSED TEMPERATURES. CONDENSING THE DRY GAS REQUIRES SUBSTANTIAL REFRIGERATING UNITS.

and deposited in the delicate parts and mechanisms of the chlorinator and, therefore, much thought has been given to eliminating them from liquid chlorine marketed for use in gaseous-chlorine dispensing units.

The total quantity of impurities is nearly always less than the sensitivity of scales used to weigh the shipping container and, therefore, has no significance as a diluent or inert material. A few years ago these impurities were present in liquid chlorine in the order of 0.2% by weight. However, by the process of purification just described, these impurities can be limited to not more than 0.01% by weight. This concentration has been found quite satisfactory for use in chlorinators.

CHLORINE PACKAGES AND DISTRIBUTION

The finished bulk chlorine under pressure is a heavy liquid varying quite sharply in volume in proportion to temperature variations. Its volume-temperature behavior is shown in Figure 8. The average specific gravity of liquid chlorine is 1.5. In this condensed state, it is packaged quite economically in approved steel pressure vessels of convenient sizes, ranging from small cylinders (I. C. C. Class No. 3A480)[13] holding 10, 15, 25, 100, and 150 lbs. each to tank cars holding 15 tons (multi unit), 16 tons (single unit), and 30 tons (single unit) each. The permitted tank cars for chlorine are I. C. C. Class. No. 106A and 105A. The conditioning and safe handling of these units is covered later in this paper. At the plant the liquid chlorine is stored in large steel tanks as shown in Figure 9.

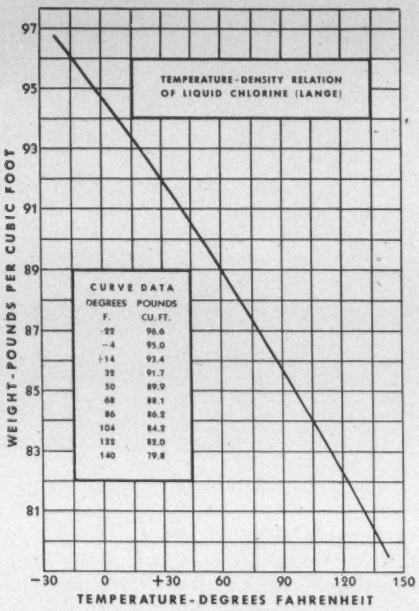


FIG. 8.

Much of the chlorine produced is used in the plant for other manufacturing operations. Principal current large users of this captive chlorine are the several synthetic, organic, manufacturing processes so essential to modern life. Typical ones are the production of ethylene glycol, (principal ingredient of Prestone Anti-Freeze) and the solvents for automobile paints and lacquers, such as amyl alcohol and its derivatives. These are produced by affixing chemical radicals to certain petroleum refinery by-products. Being readily attacked by chlorine, they are more easily processed by first chlorinating them and then replacing this chlorine with the desired radical.

From the chlorine plant there flow into these organic syntheses plants caustic soda and chlorine, out of them flow back to the chlorine plant salt and hydrochloric acid.

Likewise, plant chlorine is used to convert napthalene, a coal tar derivative, into useful resins. The production of chlorine bleaches (Fig. 10), chlorinated hydrocarbon solvents, and large tonnages of iron coagulants for water purification and sewage treatment also utilizes plant chlorine.

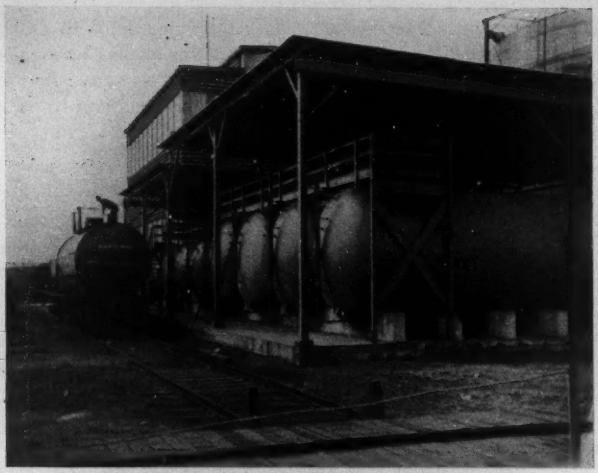


FIG. 9.—LIQUID CHLORINE STORAGE. DESIRABLE FEATURES ARE VENTILATION AND ACCESSIBILITY.

FIG. 10.—CHLORINATED LIME. INTO ONE END OF THIS NOISY TUMBLING DRUM GO CHLORINE AND LIME—OUT OF THE OTHER END COMES CHLORINATED LIME.

Hydrogen and Hydrochloric Acid. Referring again to Figure 3 it will be noted that the caustic soda accumulating at the cathode drains off as a dilute liquid and the hydrogen bubbles out as a gas. By means of blowers (Fig. 11) a portion of the hydrogen is conveyed to the acid

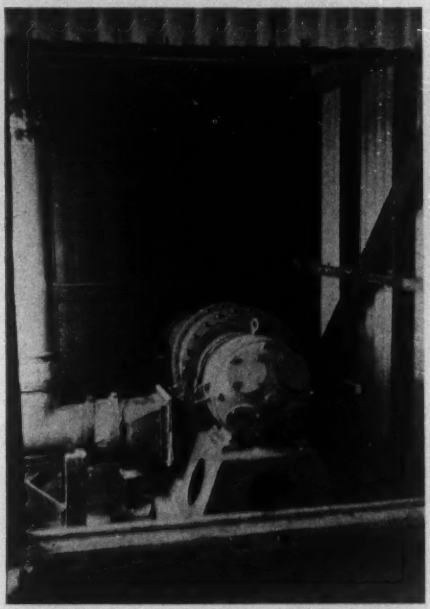


FIG. 11.—MOVING CHLORINE GAS. CAPTIVE (USED ON PREMISES) CHLORINE GAS IS SHUTTLED AROUND WITH THESE SIMPLE BLOWERS.

plant where it is burned in an atmosphere of chlorine gas to form hydrogen chloride gas, which after being cooled in suitable apparatus is easily absorbed in water to form the hydrochloric acid of commerce. Three strengths are prepared:[14] 18° Beaumé (27.9% HCl), 20° Beaumé (32% HCl), and 22° Beaumé (35.8% HCl). These strengths are shipped to consumers in carboys of glass holding 12 gals. each and rubber-lined tank cars holding 4,000 gals. and 8,000 gals. each.

Substantial quantities of hydrogen in chlorine plants are piped direct to other plants on the premises which use it to solidify vegetable and fish oils by hydrogenation. Likewise, hydrogen produced is converted into another useful product, synthetic anhydrous ammonia, by combining it with atmospheric nitrogen. Both of these hydrogenation

syntheses are accomplished with the aid of special catalysts and extraordinary pressures.

Caustic Soda. The caustic soda solution draining from the cells is weak and highly contaminated with salt. Also present in much smaller quantities are silica, iron, and manganese. These must be substantially removed from the finished caustic before it is marketed. The weak liquor,[15] containing 10% caustic soda and 15% undecomposed salt and smaller quantities of other impurities, is fed to vacuum forced-feed evaporators, where it is concentrated to 50° Beaumé (49.2% NaOH), heat being supplied by exhaust steam. Salt precipitated during the boiling is separated from the caustic liquor as a slurry by sedimentation in conical-bottom receivers; the salt is filtered from the slurry and returned to the brine purification process, while the caustic filtrate is sent back to the evaporators.

FIG. 12—CONCENTRATING CAUSTIC. 49.2% CAUSTIC LIQUOR IS CONCENTRATED TO MOLTEN ANHYDROUS CAUSTIC IN OPEN-FIRED CAST IRON POTS.

The 50° Beaumé liquid caustic from the evaporators is at this point almost freed of its sodium chloride impurity, a typical analysis being 49.2% NaOH, 0.25% Na_2CO_3, 1.15% NaCl, 0.01% Na_2SO_4. However, in order to meet the requirements of the trade further,

removal of NaCl is necessary. This is accomplished by precipitating it with Na_2SO_4 as a double salt, settling and filteration. The filtrate[16] will average 49.2% NaOH, 025% Na_2CO_3, 0.12% NaCl and 0.10% Na_2SO_4. This purified liquor is fed to the finishing department. A substantial portion of this 50° Beaumé liquor is marketed as such to the trade in 8000-gal. tank cars, rubber-paint lined, I. C. C. Class. No. 103.

FIG. 13.—PACKAGING SOLID CAUSTIC. MOLTEN (700° F.) CAUSTIC IS RUN INTO NON-RETURNABLE DRUMS AND, AFTER SOLIDIFYING, SHIPPED TO MARKET.

The caustic finishing department usually consists of a battery of cast iron pots, 10 ft. in diameter, 7 ft. deep at the center, and with a wall thickness of about 3 in., open fired by fuel oil or coal burners (Fig. 12). The liquor is completely dehydrated in these pots, the volume being kept constant by addition of 50° Beaumé liquor to replace the water evaporated. After precipitation of iron and manganese, the fused caustic is cooled to 700° F. and pumped into steel drums of 750 lbs. net capacity, where it solidifies.[17] It is shipped to market in these drums (Fig. 13).

Flake caustic soda is also produced from molten caustic. The usual flaking machine consists essentially of a water-cooled drum,

immersed ¼ to ½ in. in a reservoir of molten caustic. Rotating concontinuously at from 20-40 r.p.m.,[18] the drum picks up a layer of the caustic soda which, after solidifying on the cool drum surface, is scraped off by a "doctor" into a hopper equipped with a device to break up the sheet into small pieces (Fig. 14). The flake caustic is

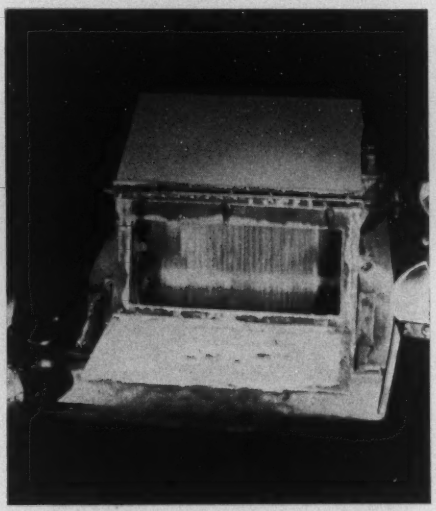


FIG. 14.—FLAKING CAUSTIC. MOLTEN ANHYDROUS CAUSTIC IS PICKED UP AND SOLIDIFIED ON A REVOLVING WATER COOLED DRUM. A "DOCTOR" SCRAPER REMOVES IT.

then packed into steel drums by means of a screw conveyor. These drums have a capacity of 400, 100, or 50 lbs.

A typical analysis of these several forms of completely dehydrated caustic soda is: Total Na_2O 76.6%, NaOH 98.2%, Na_2CO_3 0.85%, NaCl 0.4%, Na_2SO_4 0.2%, SiO_2 0.02%, Al_2O_3 0.005%, CaO 0.003%, MgO 0.003%, and Fe 0.0008%.

Not all of the caustic soda is shipped to outside consumers. A goodly portion of it finds uses in the chlorine plant for the production of other chemical products previously described.[19] Sodium hypochlorite bleach (15.5% NaOCl) is prepared by combining chlorine with diluted, well cooled caustic soda. Another important captive use of caustic soda is the production of sodium orthosilicate (Na_4SiO_4), for detergent markets by causing silica (SiO_2) to react with caustic soda.

The estimated total 1936 production of electrolytic caustic soda for the United States was 478,300 tons.[20]

Ferric Chloride. Ferric chloride in concentrated aqueous solution is prepared by using the waste chlorine and hydrochloric acid to dissolve scrap iron and steel (Fig. 15). Hot acid ferric chloride solution

FIG. 15.—OLD FORDS, PIPES, AND BEDSTEADS DON'T HAVE MUCH CHANCE WHEN THE HOT FERRIC CHLORIDE HITS THEM.

(39%-45% $FeCl_3$) is brought in contact with the iron scrap in acid proof brick-lined tanks, and a portion of its $FeCl_3$ content is converted into $FeCl_2$ by losing one third of its combined chlorine to the Fe atom passing into solution. This hot ferric and ferrous chloride effluent is pumped to the top of an absorption tower[21] where it is released and cascades down through the tower, coming in contact there with the waste chlorine which oxidizes the ferrous chloride in the liquor back to its original ferric state. The $FeCl_3$ content is kept constant by addition of water at this point to compensate for the increase in $FeCl_3$ concentration due to pickup of Fe ions in the dissolving tank and Cl ions in the tower. A portion is bypassed from process to storage tanks, and the remainder returned to the dissolving cycle.

The tendency of the finished liquor to precipitate $FeCl_3.6H_2O$ crystals on cooling limits the concentrations which are shipped to consumers, since these crystals impede unloading operations and prevent removal from the car of substantial quantities of the $FeCl_3$ purchased. These concentrations range from 40% $FeCl_3$ in midwinter to 45% $FeCl_3$ in midsummer, an actual average of several years' shipments being 42.8% $FeCl_3$. A typical analysis of the finished product is:[22] $FeCl_3$ 42%; $FeCl_2$ 0.3%; HCl 0.3%. It is shipped to small consumers in 12-gal. carboys and to large consumers in rubber-lined tank

cars (I. C. C. Class. No. 103-B) holding 4000, and 8000 gals. respectively.

The principal market for ferric chloride made by this method is found in municipal sanitation as a coagulant, particularly for dewatering sewage sludge prior to mechanical vacuum filtration.

Packaging Liquid Chlorine

Supervision. Classified as one of the commodities to be regulated in Interstate commerce under the provisions of the Act of Congress of March 4, 1921, chlorine shipments are rigidly controlled by the Interstate Commerce Commission.

All chlorine shipping containers are registered in the Bureau of Explosive's office at 30 Vesey Street, New York City,[23] and an individual record of retests and serviceability is kept there for every chlorine cylinder or tank car in service in the United States.

Purchase Specifications. The existing specifications for liquid chlorine, recommended by the several trade associations, are badly in the need of rewriting. They mean little and are not worth very much in adjusting complaints. "Not less than 99.5% pure", "shall not deposit a film . . . so as to obscure the visibility", "shall not be overloaded to excessive pressure", "defective containers . . . shall be rejected", etc. are typical of the present shortcomings of the standard specifications.[24]

The quality sections of chlorine specifications need to be completely rewritten around a dependable analytical method. Too often sloppy work in the chlorine filling station is explained by reference to consumers' picayunishness and, also, careless or uninformed operation of chlorinators in customers' plants covered up by a mentally lazy blaming of the manufacturer. In making this criticism I admit that much remains to be done on analytical methods for chlorine impurities, and it is hoped that newer methods now being developed will be released shortly.

Authorized Chlorine Packages. The sizes of the various chlorine packages (Figs. 16 and 17) are:[25]

Express, less carload and box carload movement. (I. C. C. Class. No. 3A-480)

Net Contents—lb.	10	15	25	100	150
Average Tare Weight—lb.	21	37	51	93	123
Average Gross Weight—lb.	31	52	76	193	273
Car Load—cylinders	—	—	—	150	111

Tank Car movement.

	Multi Units		*Single Units*	
Net Contents—lb.	30,000		32,000	60,000
I. C. C. Class	106-A		105-A	105-A

Shipping limitations for tank cars.

Multi-units (ton container cars) may be consigned only to private sidings or to *approved* public sidings. Single units may be consigned only to private sidings.

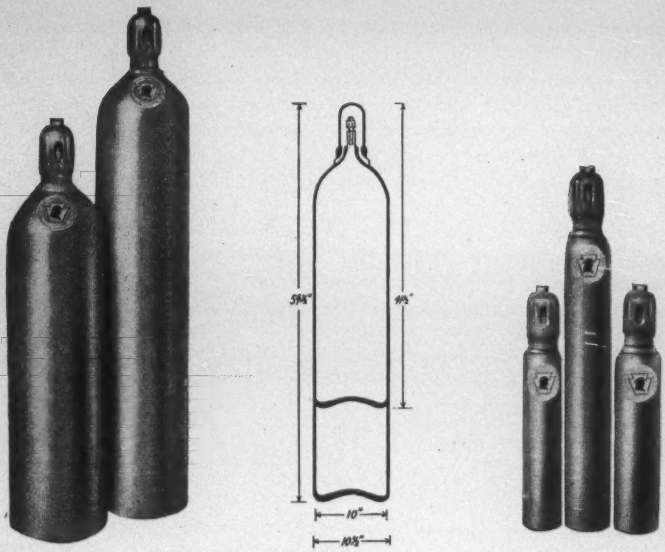


FIG. 16.—VARIOUS SIZES OF CHLORINE CYLINDERS.

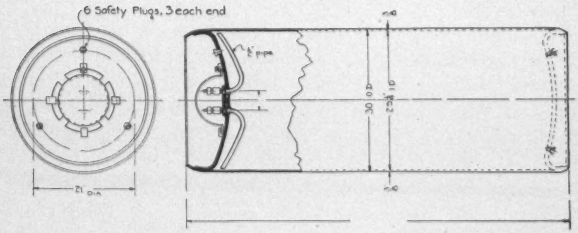


FIG. 17.—CROSS SECTION OF A TON CONTAINER.

SAFE HANDLING OF CHLORINE[26]

Cylinders. The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70°F. is approximately 35 lbs. per 24 hours for a 100-lb. and 150-lb. cylinder. This rate may be increased by improving the circulation of air

around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100°F. Even this procedure is not recommended for use in conjunction with a chlorinator since uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities.

Caution: As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures, so be sure to close the cylinder valve as soon as the cylinder is empty.

Chlorine cylinder installations should preferably include a scale to check discharge rates and weights. The dial type of scale with its platform set flush with the floor is neater and more convenient than the portable type of beam scale.

Multiple Unit Tank Cars—(Ton Containers). The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car. The approximate overall dimensions of this car are: Length, 43 ft.; width, 10 ft.; height, 7 ft.

This container must never be subjected to direct heat from any source, because the three fusible plugs in each end of the container melt at 157°F.

Each container (Fig. 17) is equipped with 2 valves, 2 internal eduction pipes, 3 safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except that they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 lbs. of chlorine per day. However, they are particularly applicable where:

1. The consuming point is at an inconvenient distance or location from the railroad siding.
2. Temperature control of tank car lots of chlorine containers is desired.

3. The chlorine is used in two or more widely separated points in the consumer's plant.

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists. A heavy rod or chain assembly in the shape of an inverted "V" and equipped with hooks is a simple form of lifting

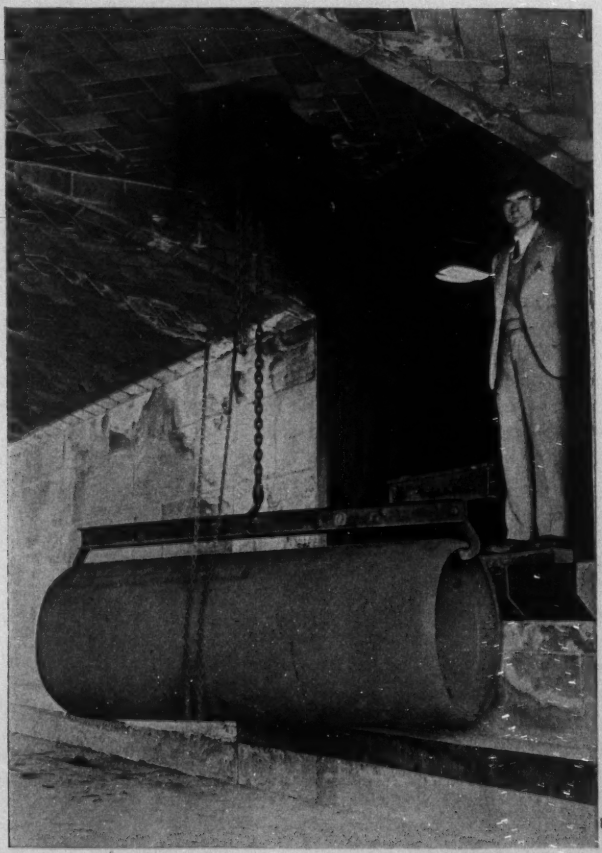


FIG. 18.—A MOST PRACTICAL LIFTING BEAM FOR TON CONTAINER. NOTE THAT IT IS PARTICULARLY APPLICABLE WHERE HEAD ROOM IS LACKING.

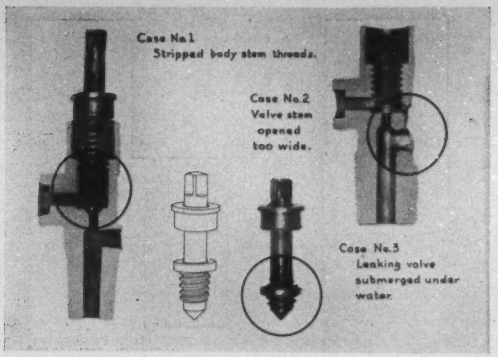
device. However, the lifting beam illustrated in Figure 18 is recommended as a less hazardous and more durable device as well as one which requires less head room.

Space does not permit illustrations and descriptions of suitable ton-container handling systems. A comprehensive discussion will be found in the Journal of American Water Works Association for November, 1934.

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 17. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing. This procedure produces material saving in floor space.

Reconditioning Cylinders. All cylinders are carefully cleaned with steam and dry air when returned to the plants. All valves are completely dismantled and polished; parts are examined for wear or corrosion and replaced where necessary. Valves are then fitted with new packing, and tested for leaks and workability before being placed in service. Loaded cylinders are checked for leaks and then held for forty-eight hours and again checked for leaks before shipment. Given reasonable care a chlorine cylinder valve will not usually cause trouble. Wrenches for operating these valves should be specially designed for this service and should never be longer than 7 in. They are usually furnished without charge by the chlorine manufacturer in order to promote safety in chlorine handling.

Figure 19 illustrates the results of typical mishandling of valves. The first[27] is a case of stripped body stem threads, often encountered and of serious consequences. This was evidently caused by pounding the valve when closed. Brass threads strip easily. The second is a reverse of the first—i.e., hammering the valve open after the maximum opening was obtained. Note that the monel metal stem acme threads have been driven into the brass packing retaining ring. The usual comment in this case is "valve stem very tight—please ship us good valves." The third indicates the futility of depending on submergence under water as a waste disposal measure for leaking chlorine units. This is one of two leaking valves on cylinders that were thrown into a water works intake pond last summer. Note that the valve is substantially eaten away and remember that chlorine is very sparingly soluble in water above 49.2°F. and very slowly soluble at that. The water was 5 ft. deep at the point of submergence and the chlorine, now completely out of control, and reach, bubbled merrily, faster and



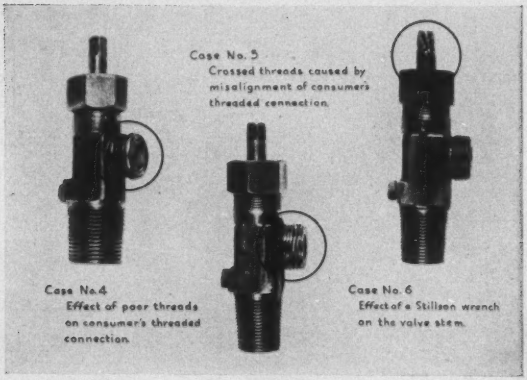


FIG. 19.—MOST FREQUENT TYPES OF MUTILATED CHLORINE CYLINDER VALVES.

faster, up through the water and was wafted by a gentle breeze across expensive plantings and into the water works plant. Its action on the plantings and water plant wasn't so gentle. Consternation was extant. The comment, "You've caused us much trouble. Please ship good cylinders. . . . Our grounds are in horrible condition. Sixty-five trees are dead. . . . " Well, I should think so. Warm water—leaks that could have been stopped by a little timely mechanical application—a wind blowing towards them—yet into the pond went the cylinders, and out of the pond like a chasing demon came the chlorine, faster and faster—brown went the trees—"tap, tap", went the typewriter.

Valve 4 is a case of poor threads on the consumer's union connection. Note the perfect condition of the face of this valve. This

condition would have been avoided by using a good connection or, better still, a clamp and adaptor, gladly furnished at no charge by the cylinder owner. Valves 5 and 6 are clear cases of carelessness. One wonders about supervisors who will allow such mutilation of the sole mechanism that stands between the human beings in the building and (in a 150-lb. cylinder) 750 cu. ft. of chlorine gas, enough to provide a lethal concentration in 375,000 cu. ft. of confined space. One wonders about the qualifications of such operating oafs to handle water purification operations, essential to the public health of the community. They should be pushing wheelbarrows instead of operating chlorinators. This mutilation of perfectly good equipment falls in the same class as citizens using a 36-in. pipe wrench to open and close fire hydrants, a practice which every water works superintendent detests.

Analysis of Some Recorded Accidents

Chlorine accidents may usually be handled to avoid noteworthy injury to human beings because of the difference between the concentrations of chlorine in air at which it is detectable as compared with concentration at which it becomes irritating or dangerous. These have been stated by the Bureau of Mines[28] to be as follows:

	P. p. m.
Least detectable odor	3.5
Least to cause throat irritation	15.1
Least to cause coughing	30.2
Dangerous for 30-minute exposure	40-60
Rapidly fatal for short exposure	1000

As proof of this safety factor which the nature of chlorine provides for chlorine users, there is listed below a complete record of all the chlorine cylinder accidents involving injury to human beings by cylinders from one chlorine manufacturer during 1935 and 1936.[29]

July 11, 1935. Cylinder failure. Several light gas cases held to be due to use of *"all service" gas masks in poor condition.*

July 17, 1935. A 150-lb. cylinder which had been shipped on August 12, 1933. There was a slight leak in an auxiliary valve in the gas line, and the chlorine shipper was notified. A service employee of the chlorine shipper, upon noticing that the leak did not increase when the auxiliary valve was open, disconnected the line. However, the cylinder valve was open and quantities of gas escaped. Upon failure to stop the leak by upending the cylinder in a nearby shallow stream, and also in the muddy bank of the stream, the fire department was called and *firemen equipped with masks capped the cylinder valve.*

January 13, 1936. When opening the valve of a 100-lb. cylinder, *they used an 18-in. Stillson wrench* and in so doing *damaged the valve stem to such an extent* that immediate closure was difficult. The man that opened the valve was gassed to a slight extent, and it was necessary for another man to close the valve. Some chlorine gas was released in the building, but no damage was reported. The man gassed in opening the cylinder lost two days from work and then made full recovery.

May 26, 1936. A 150-lb. cylinder developed a tight valve in service, and the attendant on duty attempted to remove it from service. He closed the valve and then disconnected the auxiliary valve from the cylinder valve thinking that he had obtained complete closure of the cylinder valve. The cylinder valve, however, was not entirely closed and the chlorine escaped rapidly into the filter building. The attendant donned a gas mask and attempted to remove the cylinder from the building. *The mask was improperly adjusted to the contour of his face and he received a severe dose of chlorine because of this negligence.*

August 12, 1936. The apparatus consisted of a dry-feed chlorinator and a 150-lb. cylinder of chlorine. During power interruption, the recirculating pump and chlorinator for this pool were shut down and for some reason, not definitely fixed during the investigation, a quantity of chlorine gas collected in the piping system. When the pump was restarted, this was swept out into the pool and, due to the fact that the water level was below the influent pipe, this gas was discharged over the surface of the water. The swimming instructress, and eight little girls were near the influent pipe at this time and were affected by the this chlorine. Several of the girls began to cough before the instructress noticed any odor of chlorine. The odor completely disappeared from the room within five minutes. After being examined by a physician and given first aid at the infirmary, two girls were made slightly ill and vomited; none were unconscious or affected with nose or throat discharges.

1936—Exact Date Undisclosed. This customer *attempted to avoid purchasing a chlorinator by discharging chlorine gas from a 100-lb. cylinder into an open barrel filled with water through which a stream of cold water was continually passing* to discharge into the water plant discharge line. A borough official in reporting this accident said in part: "We tried to open the valve a trifle and opened it too much. When we attempted to close the valve we found it frozen. We filled the reservoir with gas and almost killed a man or two. We finally managed to unscrew the hose and put the cap on the valve

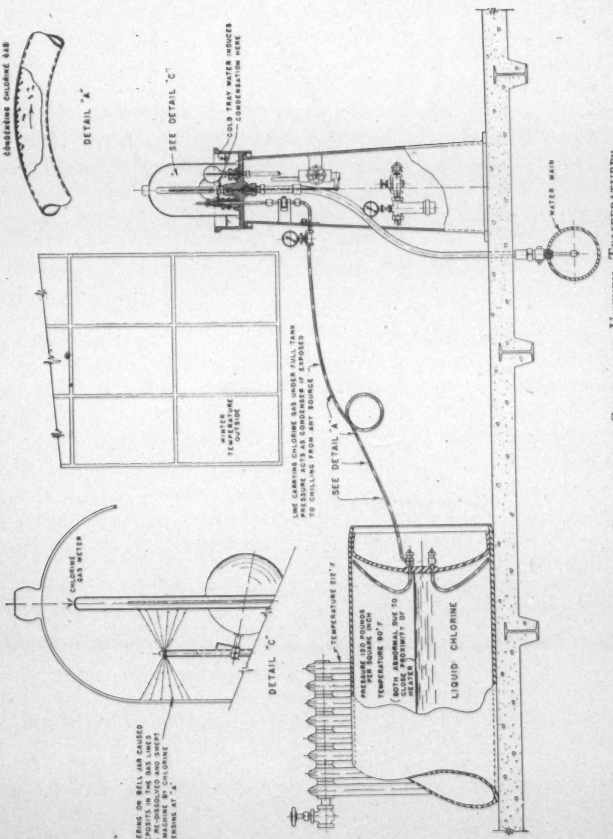
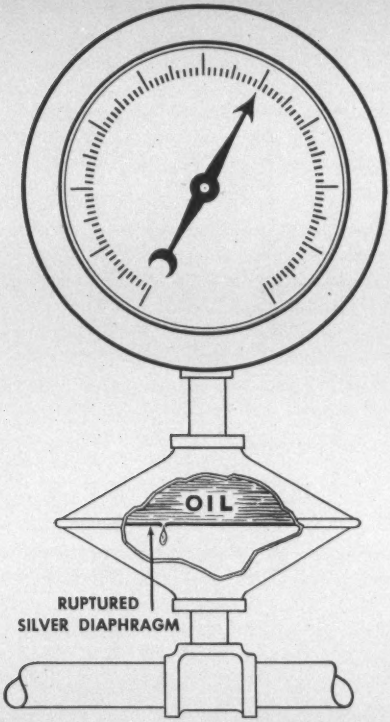

CHLORINE GAS
DETAIL "A"
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
WATER MAIN
WATER TEMPERATURE OUTSIDE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE AND SOLD CONDENSED IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
CHLORINE GAS METER
ENTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO WATER BY CHLORINE CONDENSING AT "A"
DETAIL "C"
TEMPERATURE 30° F
PRESSURE 20 POUNDS PER SQUARE INCH
TEMPERATURE 90° F
BOTH ABNORMAL DUE TO CLOSED EFFECT OF HEATER
LIQUID CHLORINE

FIG. 20.—CONDENSATION DIFFICULTIES CAUSED BY UNEVEN TEMPERATURES.



The ruptured silver diaphragm exudes oil which upon chlorination is converted into sticky waxes. These waxes are swept into the machine by the influent chlorine gas.

FIG. 21

outlet." Subsequent investigation indicated that no one was seriously injured.

1936—Exact Date Undisclosed. Customer reported by mail that the fusible plug of a 100-lb. cylinder had leaked and caused a rather severe gassing of the two boys who removed the cylinder from the building. Examination of the cylinder revealed pitted stem seat and chewed up fusible plug, which indicated *contact with moisture.*

It will be noted that out of seven cylinder accidents involving

injury to human beings five were caused by careless or inexperienced handling of chlorine equipment, one was due to a tight valve and one to a defective cylinder. Also defective masks or improper handling of gas masks gave a false sense of security and caused human injury in three cases. Fear, excitement, and inaccurate reporting by the newspapers characterize chlorine accidents. This is largely due to panic induced by the unpleasantness of chlorine at less than irritating concentrations. A careful, informed worker seldom has any difficulty. This is another important water works duty that requires the services of properly trained personnel. Changing water purification plant operators following each political change in a municipality does not promote a good chlorinator operation. It is imperative that only properly informed persons who are free from respiratory disturbances, particularly asthma, be given chlorine duties in a water plant.

The most frequent causes of chlorinator plugging are illustrated in Figures 20 and 21.

Acknowledgments. In collecting and condensing this material I was greatly encouraged by production executives, Hardcastle and LeBar, and materially assisted by technical coworkers, Gibbs, Sweetland, Cushing, and Underwood. The candid and helpful comments of Penfield, Enslow, and Baldwin strengthened the paper. Faber's willingness to poke his good camera here and there, in very corrosive places, made possible the illustrations at a time when an unforeseen emergency threatened to leave the paper pictureless. It is only fair that an expression of gratitude be made to these good folks.

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*Pennsylvania Salt Manufacturing Company

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(29) P. S. M. Co. records.

Discussion

DONALD C. CALDERWOOD.[1] What is the best thing to do when a chlorine valve leaks and cannot be shut off?

Mr. HEDGEPETH: Use the tank. If a valve or cylinder leaks and the chlorine cannot be used, there isn't anything to do but empty the tank. Empty it into lime slurry. Since 1.25 lbs. of mason's hydrated lime will absorb 1 lb. of chlorine, 125 lbs. of lime, purchasable from any hardware store will absorb the entire contents of a 100-lb. cylinder. The cylinder should be turned upside down and the chlorine blown out through a flexible connection, into the lime slurry. The slurry should be prepared by mixing 10 gals. of water with each 5 lbs. of lime used. The cylinder may not be shipped back to the chlorine company. The I. C. C. forbids it. If the railroad knows that a cylinder has a bad valve, they won't take it. A person shipping a leaky, or defective, loaded chlorine cylinder is committing a criminal act.

ROGER W. ESTY.[2] Will Mr. Hedgepeth describe another method of preventing reliquefication of chlorine gas in the feed lines. He has shown that it can be done by providing a drip leg.

Mr. HEDGEPETH: It can be done by a pressure-regulating valve. If the pressure is regulated better operation results. The pressure regulating valve should be inserted in the line between the chlorine cylinder and the chlorinator, preferably as near the chlorine cylinder as possible. Usually 55 to 65 lbs. of pressure are all that is needed; even 40 lbs. will operate a chlorinator, and if the pressure in the chlorine lines and the chlorinator is kept below that point there will be no trouble with reliquefication.

LINN H. ENSLOW.[3] One of the worst cases of reliquefication I ever saw was in the desert where there was no deficiency in temperature. Reliquefaction is not so much a matter of the variation in temperature as it is a matter of the relationship between what we may call the condensing pressure and the temperature at which the chlorine reliquefies, at such pressure. In other words, chlorine gas may be very warm, as it was in the desert,

[1]Nashua, N. H.
[2]Danvers, Mass.
[3]New York, N. Y.

and may be cooled a couple of degrees to result in reliquefication if the pressure is high. I was anxious for Mr. Hedgepeth to stress this matter of pressure reduction on chlorine gas lines. It is good for safety as well as for the avoidance of operating troubles, and I am frank to tell you if I was operating a chlorinating plant now, knowing what I do, I would invariably put in a pressure-reducing valve of some nature right at the cylinders or the ton container, or near that point, and carry only 30 or 40 lbs. of pressure in the gas line. You could then run the gas line to the North Pole and back and not get any liquefication.

When it comes to emptying a leaking cylinder there is another method. It may not be suitable in many cases, but it is used considerably now. That is a strong compartment, or vault which will withstand the normal pressure that a chlorine cylinder would carry, say up to 120 lbs. per sq. in., at least. Have a good gasket on top, put the cylinder or ton container into it, put the top on, using the gasket, and have a connection outlet from the compartment. Then you can merely use up the chlorine that leaks by carrying it through the chlorinator and thereby make use of it. When exhausted, remove the empty cylinder and ship it back.

DONALD C. CALDERWOOD. Could Mr. Hedgepeth tell us something about chlorine ice observed in cold weather?

Mr. HEDGEPETH: Chlorine ice is a compound of chlorine and water that solidifies above the freezing point of water. There are several forms. A frequent one is $Cl_2 \cdot 8H_2O$. It will not form at temperatures above 49.2°F., nor in low concentrations of chlorine in water. The most common point of its formation is in the bell jar where low-pressure chlorine is present in high concentrations. I know of only one permanent cure and that is to put some heat into the bell jar. This may be done by slightly warming the influent chlorine gas. Heating devices for this purpose are available from chlorinator manufacturers. Another dependable method is to warm the tray water to 50°F., or above. *Do not exceed 80°F.* It is unnecessary to warm the entire chlorinator water supply—just the little stream required for the tray. If you separate it from the injector supply, a 750-watt standard water heating unit will keep the tray water supply at satisfactory temperatures. To repeat, when the water is below 49.2°F. and the concentration of chlorine is heavy, chlorine hydrate will certainly form. It has nothing to do with the quality of liquid chlorine, or method of operation. It is solely a matter of chlorine concentration and temperature.

RELINING AN ELEVATED STORAGE RESERVOIR WITH GUNITE.

BY ROGER W. ESTY*

[*Read November 18, 1937.*]

This paper on the reconstructing and relining of a storage reservoir with Gunite should be divided into two parts, namely: first the history, telling why this reservoir was originally constructed, and secondly the procedure of relining this structure with Gunite.

History of Wills Hill Reservoir

Delving back into history, previous to 1876, Danvers, a town of approximately 5600 in population located in the southern part of Essex County, was without a water supply. This matter was brought up for discussions in town meetings held in 1869-1870. On April 24, 1874, an act of the legislature gave the town the right to construct a water works system.

About this time the Commonwealth of Massachusetts was considering the building of a hospital in Danvers and was confronted with the problem of obtaining a satisfactory water supply. The state and town got together in this mutual requirement and agreed to go into a partial partnership on a water works system. On June 23, 1876, an agreement was made whereby the state should construct a 5-m. g. reservoir and forever maintain it and the town should construct a pumping station, distribution system and forever keep this reservoir full, a certain yearly sum to be paid for the water to the town for a term of twenty years. This reservoir was situated 2.6 miles from the pumping station. There was, between the pumping station and the reservoir, a 12-in. sheet iron, bituminized, lined pipe coated with cement. This proved quite satisfactory for several years.

In 1892, the Water Commissioners called to the attention of the citizens the weakened condition of this force main in the following statement:

The force main has burst several times and will probably continue to do so, as there is an average of 10 lbs. more pressure on it when the engine is pumping than on the rest of the pipes. The pipes are so small that it takes three tons of coal to do the work of what two should if the pipes were of a proper size.

In the following year another statement was made by the Commissioners, which indicated that the condition of the force main was a serious problem and required immediate attention:

*Superintendent, Danvers Water Works, Danvers, Mass.

Attention has been called in previous years to the apparent weakening of the force main owing to the increased pressure caused by forcing the water through too small a pipe. When the engines are working the pressure indicates 86 lbs. which with a 24-in. main should not be more than 70 lbs. There is also about one-fourth more coal consumed to produce the same result than would be with a pipe of proper size.

There were eight bursts last year in the force main as against an average of one for several previous years, and as they occurred when the ground was frozen and also in one instance flooded a factory basement in Middleton, the cost to the town was over $500.00.

The commissioners would recommend that the sum of $5,000.00 be appropriated to build a reservoir of stone on Wills Hill, 1000 ft. from the engine house, to be 125 ft. in diameter and to hold 700,000 gals., and connected with the pumps and force main with a 24-in. iron pipe.

The water would be forced to the new reservoir with the smallest possible loss of friction and would flow by gravitation to the reservoir at the Asylum, taking 28 lbs. from the pressure main, which would help it to last perhaps for many years. But if a new force main must be laid this plan would be the best, as a 12-in. force main would be large enough if not pumped into direct, and would cost with the proposed reservoir $15,000 less than a 24-in. direct from the engines to the main reservoir.

No time was lost by the Commissioners for again in 1894 they said the following:

The commissioners are of the opinion that some measure should be taken to relieve the force main, as great care has to be used in pumping the water.

It seemed that each year this problem was a serious one in the minds of the Commissioners. As one reads through some of the early reports particularly in the late eighties, one readily sees that it was very difficult for the department to obtain sufficient income to carry on the fixed overhead. It was necessary many times to borrow money to pay every day expenses.

In their 1895 report the Commissioners spoke about the main in the following manner:

In our last report we called the attention of the town to the importance of some action being taken in regard to the force main pipe, which we consider unsafe; there are more or less breaks and leaks in the pipe, and we look for serious trouble at no distant day. We wish to bring the matter before the town again, and recommend that immediate action be taken.

At the annual town meeting of 1896 this matter was brought

before the town for definite action and the following is the special report and the report of Mr. Bishop, Engineer:

REPORT OF EXPERT

Middletown, Ct.

To Geo. W. Fiske,
Chairman Water Commissioners, Danvers, Mass.
Sir:—

Having considered the propositions presented to your Board, viz:— The laying of a 24-in. pumping main from pumping station in Middleton to Hospital reservoir, 2½ miles; also the suggested plan of constructing a distribution reservoir on Wills Hill, 1800 ft. distant from pumping station, and connecting the new reservoir on Wills Hill with the Hospital reservoir by means of your present main, thus pumping the water into Wills Hill reservoir, and then conveying same to Hospital reservoir by gravitation, thence, as heretofore to Danvers.

This latter plan has my approval as being the most desirable for your board to adopt for the following reasons:—The cost of a 24-in. main, 2½ miles in length, would be about $45,000, and would reduce the frictional resistance to a minimum of say 3 ft. above the actual head.

The contruction of an earth reservoir with flat slopes (two feet horizontal to one perpendicular) made in a circular or elliptical form. The top of embankment to be 12 ft. above present surface of ground on the highest part of Wills Hill, lining same with two coats of asphalt, making a half inch thickness as a security against leakage, with a capacity of 1½ m.g., for a sum not to exceed $12,000, including a 20-in. pumping main, from pumping station, also independent connections with your new reservoir and your present main, gates, screens, etc. This would require the actual lift of the water about 8 ft. more than by the 24-in. main, but would reduce your present lift by the 12-in. main nearly 60 ft., and consequently very materially lessen the strain now produced on the present pumping main, hence rendering it liable to be useful for many years. In any emergency a new 12-in. main can (at present prices) be laid parallel and by the side of your old main for 2½ miles, within the sum of $17,000. The practice of modern water works construction is to duplicate by independent lines as far as possible in reenforcing the present works.

This second plan gives you two reservoirs that can be used together or independently in the emergency of repairs or cleaning process. Also an improved service to your patrons at Middleton, more desirable for Danvers if necessitated to supply temporarily via the 8-in. line through to the west and south of the Asylum. For these general reasons I recommend that the reservoir on Wills Hill and connections be constructed at an early date, leaving the proposed new

12-in. main to be added to this plan at such time as the necessity of the case may require.

Respectfully submitted,

GEORGE H. BISHOP, Engineer.

Middletown, Ct., March 24th, 1896.

REPORT OF THE WATER COMMISSIONERS ON THE FORCE MAIN

The town having referred back that part of the report of the Water Commissioners that relates to the force main pipe to examine into the matter and report back to the town the best plan for remedying dangers that the town is liable at any time to meet, would submit the following report and recommendations:—

The committee have attended to their duty, made a thorough investigation, have employed experts and attach to our report the recommendation of George H. Bishop of Middletown, Conn., who was engineer when the works were established.

It is fully understood by the citizens of Danvers that our force main is not capable as at present used to do the work required of it; that there is too much pressure on account of the size of the pipe in pumping direct to the reservoir, and consequently we have breaks and leaks and these are increasing each year and the commissioners think there is great danger of serious trouble at no distant day. Should there be a new main laid, it must be at least 24-in. to do the work, and this would cost the town $45,000.

We believe that this large expenditure of money can be saved by constructing an earth and stone reservoir to hold 1½ m. g. on Wills Hill, and pumping the water direct to this reservoir and allowing it to run by gravitation to the reservoir on Asylum Hill. If this is done, we believe the present main pipe would last for several years to come.

It is also important to the town to have two reservoirs so that in cleaning or accident either could be used. After making a careful investigation, and our conclusions being confirmed by one of the best experts in the country, we would make the following recommendations:—

First, that a reservoir of earth and stone be built on Wills Hill, with a capacity of 1½ m. g., and that a new 20-in. main be laid from the pumping station to the new reservoir at an expense not exceeding $14,000.

Second, that the town treasurer be instructed to issue 30-year bonds at 4% interest, for such an amount as shall be necessary to complete this job, and not exceeding $14,000. The bonds to be sold

to the highest bidder, or pledged, and all premiums resulting from such sales be turned into the sinking fund.

GEO. W. FISKE
OTIS F. PUTNAM,
EDWIN TURNER, Sen.,
Water Commissioners
of
Danvers.

The following paragraph is taken from the 1896 report:

We called the attention of the town in our last report to the importance of relieving the force main pipe. At its annual meeting in March, after a full discussion of the best plan to be adopted, it was voted to appropriate the sum of $14,000 to build a reservoir on Wills Hill with a capacity of 1½ m. g. of water. The Commissioners were chosen a committee to carry this vote into effect. We at once purchased about three acres of land for the sum of $1,000 from D. W. Case. We advertised for proposals for building the reservoir, and awarded the contract to C. H. Eglee Co. of Boston. The work by them was entirely satisfactory to the Commissioners and the building of this reservoir has accomplished all that was desired or expected. The force main has been relieved of its pressure and we have had no trouble or expense with it since. Had this reservoir not been built we would have been obliged to have put in a 30-in. pipe from the pumping station to the Asylum at a cost of about $50,000 and we feel by this plan that the town has saved at least $36,000.

From our records I find that the cost of this reservoir was $13,477.29. From the report of the commissioners of 1897, I quote the following:

The new reservoir has proven a great success. The pressure on the force main shows an actual decrease to 60 lb. from the former pressure of 80 lbs. or more to the square inch. This decrease of pressure is of distinct advantage to the force main and to the engines. Formerly such a large quantity of water was forced through a small pipe that the main was necessarily affected by the throbbing of the pumps. This was especially the case whenever a leak occurred in the force main, when the relief of pressure would cause the engine to jump and strike like a hammer. The strain both to the engine and the force main must, at such times, have been great. Under the new conditions the coal has nearly 12% higher efficiency, and 25% more water than formerly can be pumped in the same time.

Even after this they still had leaks in the old 12-in. main. In the 1897 report the superintendent said:

I have to report during the year 58 leaks, of which 15 were in the 12-in.; 8 of them were in the force main between the pumping station and the Asylum reservoir all of which were joint leaks.

Apparently there were no breaks in the pipe itself, but the sleeves were gradually giving out from the past water hammer. In the 1898 report the commissioners state:

The number of gallons pumped per pound of coal was a trifle larger than last year, 336 gals. against 332 in 1897, which was the first year of the new reservoir. In previous years the duty averaged about 290 gals. per lb. of coal.

It is very apparent that in 1898 the reservoir was leaking badly, the banks had slumped, and the 3-in. cement lining that had been placed over the interior surface had disintegrated to such an extent that in 1899 it was declared unsafe and plans were made to reconstruct the interior. The report of the Commissioners at the end of 1899 tells about their decision to rebuild the reservoir upon advice of their consulting engineer, a statement that I am going to quote in full:

When the Wills Hill reservoir was built it was estimated that it would pass 1,000,000 gals. of water a day when kept full and 700,000 gals. at the height it has usually been kept. During the drought in the early summer our daily average was 900,000 gals. per day for several weeks, some days running over 1,000,000 gals. We found it impossible to keep the water in the Asylum reservoir at a height necessary for safety even by pumping 7 days in a week, without increasing the storage in the Wills Hill reservoir. We were soon aware that it was leaking badly and made the following tests.

1st,	35 hours at	15-ft. level	210,915 gallons,	6,026 per hour
2nd,	12 hours at	13-ft. level	66,709 gallons,	5,559 per hour
3rd,	12 hours at	12-ft. level	88,500 gallons,	7,375 per hour
5th,	15 hours at	7-ft. level	88,042 gallons,	5,870 per hour

In consequence of these and the very soft condition of the banks and surroundings, we called in an engineer whose report is as follows:

New York, July 31, 1899.

To The Board of Water Commissioners, Danvers, Mass.

Gentlemen:

In accordance with your instructions, I visited your reservoir on "Wills Hill," for the purpose of examining its condition and investigating the leaks you have reported to me. I find the following conditions existing, and recommend repairs as set forth in this report and as shown in the accompanying sketch.

The reservoir was built in the summer of 1896. Its construction consisted of an earth embankment 12 ft. above the surface of the ground and an excavation 6 ft. below, forming a circular basin with sloping sides, 170 ft. diameter at the top, 98 ft. diameter at the bottom and having a depth of 18 ft., the material forming the embankment being supplied from the excavation in the centre and from other excavations outside the structure. The bottom and inside slopes were

coated with crushed stone and a mixture of sand and cement, making a lining of about three inches in thickness.

On July 12th, in conformance with my request, that I would like to see the reservoir full and empty, I found a depth of water equal to about 14 ft. At this time I carefully examined the outside slope and surfaces of the ground around the reservoir, including the trenches which supplied a portion of the material for the embankment. These trenches were well filled with water and are the principal evidence of serious leakage, the amount being controlled by the height of water in the reservoir. I suggested that some trenches be dug on the outside, to see whether the water was making its way through the embankment or whether it was going through the natural earth, which forms a large portion of the Reservoir, but which had not been disturbed in its construction. These excavations proved the leakage to be in all directions, and that the water came through the natural earth as well as the embankment, which was thoroughly saturated with water.

Measurements taken at this time show the top diameter to be 169 ft. 3 in., bottom diameter 97 ft. 9 in. and the depth 17 ft. 6 in. In three years the embarkment has settled 6 in. and is still in a very soft and unsatisfactory condition. In fact, it is so soft and loose that I had no trouble in penetrating it to a considerable distance with a stick.

I visited the reservoir again on July 13th. During the night the water had been allowed to run out, and about noon the reservoir was entirely empty. I had some excavations made in the inside slope and found the water running back into the reservoir. This was due to the spongy condition of the soil, which held in suspension a large amount of water, and which returned through the same channels created by the pressure of water when the reservoir is full. A large number of places in the bottom of the reservoir had the appearance of small springs, and the water, supplied from that held in suspension in the embankment, could be seen bubbling up. Some of these places were dug out, demonstrating the fact that the leaks were through the bottom as well as through the sides.

The lining I found to be in a very bad condition and absolutely useless for the purpose it was intended. The mortar had become disintegrated and the crushed stone in many places had rolled down the slopes and lay in heaps at the bottom.

Undoubtedly the reservoir has leaked from the time it was first filled with water, but as it had never been allowed to remain full any length of time, its actual condition has not been noticed until now. It cannot be used with safety in case of an emergency or in case anything should happen to the Asylum Hill reservoir, where it would be necessary to carry the maximum depth of water. For the purpose of supplying the Asylum Hill reservoir, as you are doing at present, I would not advise you to allow more than 8 ft. of water to remain in the reservoir for more than twenty-four hours.

The accompanying sketch will give you an idea of the repairs necessary to make the reservoir what it should be. In brief, they consist of a substantial lining of stone carefully bonded together with cement mortar. The lining to be 9 in. in thickness on the bottom and sides to a height equal to a depth of 5 ft. of water, and continues on a level to the centre of the embankment, and ends with the core wall which rises to within 18 in. of the top of the embankment. The remaining portion of the sides or slopes to be rip-rap. All stone to be about one half cubic foot in size, with the interstices filled in with the crushed stone used in the present lining, and all carefully bonded together with a good quality of cement mortar. The immediate vicinity of the reservoir will furnish all the stone necessary for the lining.

The overflow pipe should be properly set in masonry, and the outside slope protected from damage in case the reservoir should overflow.

Reservoir should be kept full of water at all times to protect them from changes of temperature. The plan herein suggested calls for 5 ft. of water in the reservoir at all times, especially during the winter months, allowing 10 ft. above the 5-ft. level for rise and fall.

Respectfully submitted,

EDWARD H. PHIPPS.

In order to satisfy ourselves that accepting this advice was the best thing we could do we made a thorough investigation of the subject, visiting and corresponding with other water works officials and were satisfied that his plans well carried out would give us a tight reservoir that we could use to its full capacity. One of the Board went to Plymouth and through the kindness of the chairman of the Board made a thorough examination of the works, gaining much useful information, including the manner of building, cost, etc., of their reservoir which they built themselves. It is the same size as ours and built practically the same as recommended by our engineer. They strongly advised doing the work ourselves. There seems to be a growing feeling against contract work in the best governed places. At a meeting of the Municipal League of the United States (comprising a majority of the cities) a paper was read by one of the mayors. We wish we could give it entire. The conclusion was as follows:

"The contractor in figuring on a job takes into consideration all the elements of chance. He estimates labor at the highest price and the same with all material that he will have to use. He expects all of his excavations will be hard digging. If he gets labor at a lower price or if the excavations prove to be sand instead of clay he calls that profit. Now that the city has always to pay for the most expensive job possible why not have the city take these elements of profit for itself? There certainly is nothing to lose and the possibility of profit. If the city did its own work the men would receive at least the best going wages. The material used would always be of the best, there would be no object in using deceit in the work and I believe

that in the end there would be a large saving to the city. There is this feature that would come of the city doing its own work. Preference could be given to its citizens and in this way gangs of laborers would not come in from the outside and take the bread out of the mouths of resident working men."

The result of our investigation was a unanimous vote of the commissioners that it would be for the best interests of the town to do the work ourselves. Mr. Sears acted as superintendent under the direction of the engineer and was on the work at all times until it was finished. It was completed excepting around and asphalting the top, which will be done in the spring when all is settled and dry.

From what I have been able to obtain from the 1899 and 1900 report the cost of this work was $6,476.10. The Commissioners state in the 1900 report their satisfacton of the work in the following manner:

After finishing the repairs of the Wills Hill Reservoir we made repeated tests which failed to show the slightest leakage. We have connected it to the pumping station by means of a large gage, enabling the engineers to tell at a glance the exact height of the water. The blow-off which is in the engine house yard was laid with vitrified pipe. This was not capable of standing the pressure and broke, flooding the cellar and washing the grounds. We relaid it with iron pipe, continuing it to the pond.

In 1902 the engineer at the pumping station said:

I have visited the Wills Hill reservoir and grounds a great many times during the year and it showed no signs of leakage.

Nothing appears in any reports concerning the Wills Hill reservoir until 1912. This report clearly states the advantage of two reservoirs, as the main Hospital reservoir needed repairing and this could be easily done by using the Wills Hill reservoir to supply the two towns. The report is as follows:

The Hospital repaired the walls of the reservoir in the summer. They were bulged so badly that on part of this end they had to be taken down to the bottom. It took about four months and for nearly three months the reservoir was empty, we taking water directly from Wills Hill. This was, of course, quite expensive at the Pumping Station on account of the small capacity of the reservoir, although the normal pressure from Wills Hill is 10 lbs. more than from the Hospital reservoir, the heavy draft through the day made a great fluctuation in pressure, causing many breaks mostly in the night when the pressure went up.

This episode distinctly and emphatically emphasizes the value of duplication particularly in elevated storage reservoirs. For this particular job alone of repairing the Hospital reservoir, the Wills Hill reservoir proved to be a wise investment.

The first repairing of the reconstructed Wills Hill reservoir

came in 1914. From Mr. Newhall's report, he being the Superintendent, I quote as follows:

The rip-rapping on Wills Hill reservoir showed that it needed looking after. We drew the reservoir off and proceeded to fix it and thoroughly clean the bottom and sides. We found several cart loads of stones over the bottom and thrown down the stand pipe and inlet, leaving off the wire netting, which was forced down the pipes. As this occurred only by the aid of human hands, it showed a spirit of malicious mischief which also amuses itself in tearing pickets from the fence as fast as they were replaced. As we cannot police this place we have appealed to the Town of Middleton and trust that they may be able to stop it.

In later reports there are a number of references to the condition of the reservoir. No quotations will be given of statements prior to 1935 when we read the following:

During the year the Hospital and Wills Hill reservoirs were emptied and cleaned out. The Hospital reservoir is in splended condition. The Wills Hill reservoir should be reconstructed. The inside of this reservoir is concreted on the base and about 10 ft. up on the sides. In front of the core wall slope it was filled with gravel and then rip-rapped. The base of concrete is deteriorating rapidly and the rip-rapped slope is sliding down into the base and is all out of shape. However the reservoir does not leak, but should be given attention as soon as funds can be made available.

Efforts were made to undertake the necessary repairs as a Federal project but this never was given any real consideration. It was not until the summer of 1937 that the necessity of repairing this reservoir became a mandatory proposition. At this time the hospital reservoir was emptied to be cleaned, and while this was being done it became necessary to supply Danvers and Middleton from the Wills Hill reservoir. The cleaning process took much longer than planned, due to rains. It is always desirable to have the reservoir perfectly dry for cleaning as it takes about one quarter of the time to do so and as a much better job can be accomplished.

During this time the Wills Hill reservoir showed much leakage as compared to normal operating conditions. This may be explained as follows. Under normal conditions the water pumped from the station can follow either of two ways, to the Hospital reservoir or to the Wills Hill reservoir. We have found by readings of the Venturi meter and elevations of the Wills Hill reservoir that about half the water goes to each reservoir.

The Wills Hill reservoir is situated 25 ft. above the Hospital

reservoir. After the pump stops the water begins to run back and what is not being used goes into the Hospital reservoir. When it becomes time to pump again, on the next day, Wills Hill reservoir is entirely empty. The reservoir holds 1,678,000 gals. and at the end of each day's pumping, the reservoir probably is not over half full. As the lowest 6 ft. are below normal ground level, any leakage through the base or sides would probably not show up around the reservoir. It is only when the elevation of the water surface reaches above the 6-ft. level that leakage would show up. As it is possible to go 8½ ft. above the natural ground level, this elevated pressure has a chance of pushing out through any defective places.

So it was when the Hospital reservoir was being cleaned that we kept the reservoir nearly full for twenty-eight days and that this constant pressure gradually developed leakage which became so alarming that it necessitated the immediate changing over of reservoirs.

Out around the reservoir the material was originally excavated for the embankment. These areas were about 50 ft. wide, ranged from 50 to 150 ft. in length and were about 3 ft. deep. All of these areas showed pools of water, some overflowing and allowing the water to run down slowly over the side of the hill. As the land all around the reservoir is pasture land and there are no houses within a thousand feet, no flowage damage was encountered. The south bank showed a soft area, and we were afraid that the bank might slide out as the material was clay and loam. Tests were made of leakage and we found that during the night the reservoir, at a 12 ft. elevation, would drop about 4½ in. indicating a leakage of approximately 4,000 gal. per hour.

During and after these tests, the Commissioners and our consulting engineer viewed the conditions. It was deemed advisable to commence repairs immediately. The method of procedure to prevent future leakage was studied, and estimates were made.

Use of an 8-in. reinforced concrete slab over the entire area was considered, the slab to be provided with special expansion joints to offset any expansion or contraction that might take place. Against this method the use of Gunite was studied, and its advantages and disadvantages relative to slab concrete were compared.

We felt it advisable to consult concrete experts in this matter and a representative of the Portland Cement Association was procured to make an examination and to decide which method would be more suitable for this particular type of reservoir. There were several different slopes, and the surface was uneven. The representative leaned toward the use of the Gunite method, but he said that either

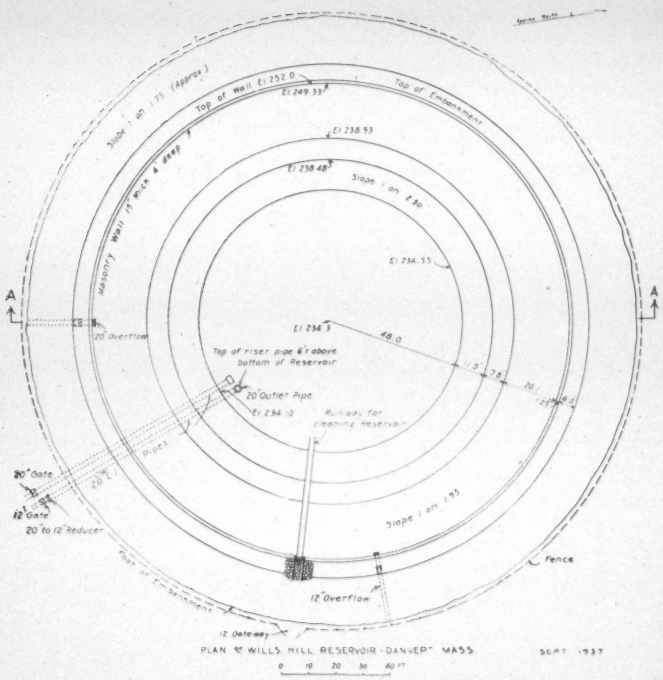

FIG. 1

method could be employed and that either, properly used, should give a tight job.

As shown in Figures 1 and 2, the rubble masonry was laid on several slopes. The base was practically level with only a 6-in. difference in elevation across it for drainage. There followed a 10-ft. 45 degree slope leading to an 8-ft. level area and a long terminal slope at two angles of probably 45 and 50 degrees.

Over this last slope there had been originally laid about 36 in. of fill and on top of this 18 in. of rip-rap to protect the upper slope of masonry from frost and ice action. The lower slope and base was to be under water at all times, the water to be held back by a 6-ft. standpipe in the reservoir. A 20-in. cast-iron pipe entered the base and a 20-in. cast-iron outlet reduced outside of the reservoir to a 12-in. diameter pipe connected into an 18-in. line that runs from the pumping station to the Hospital reservoir.

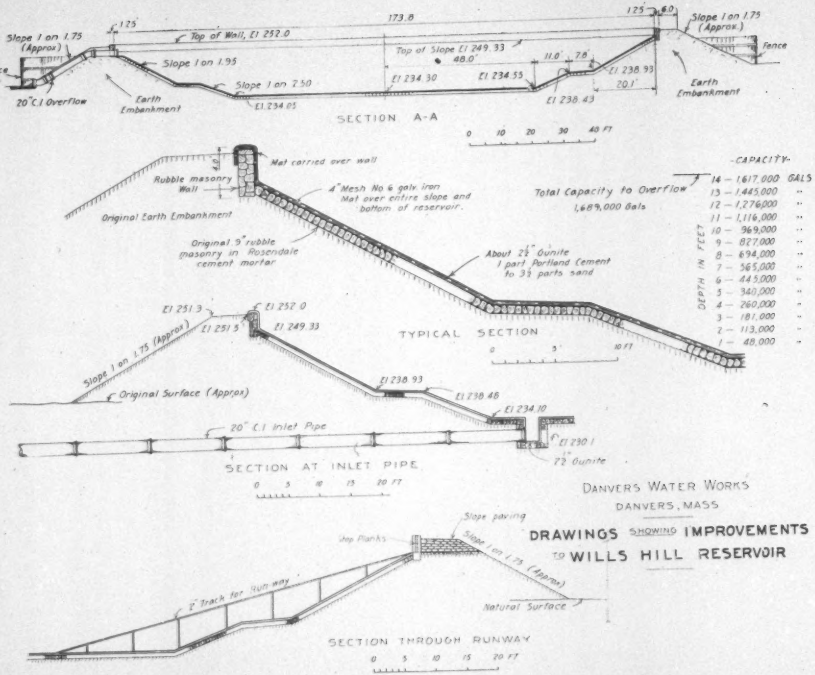
Slope 1 on 1.75 (Approx.)
Top of Wall, El 252.0
Slope 1 on 1.95
Slope 1 on 2.50
Top of Slope El 249.33
El 234.30
El 234.55
El 238.93
El 238.43
El 234.05
Fence
20" C.I. Overflow
Earth Embankment
SECTION A-A
Rubble masonry Wall
Original Earth Embankment
Mat carried over wall
4" Mesh No 6 galv. iron Mat over entire slope and bottom of reservoir.
Original 9" rubble masonry in Rosendale cement mortar
About 2½" Gunite 1 part Portland Cement to 3½ parts sand
Total Capacity to Overflow 1,689,000 Gals
-CAPACITY-
14 — 1,617,000 GALS
13 — 1,445,000 "
12 — 1,276,200 "
11 — 1,116,000 "
10 — 969,000 "
9 — 827,000 "
8 — 694,000 "
7 — 565,000 "
6 — 445,000 "
5 — 340,000 "
4 — 260,000 "
3 — 181,000 "
2 — 113,000 "
1 — 48,000 "
DEPTH IN FEET
TYPICAL SECTION
El 251.3
El 252.0
El 251.5
El 249.33
Slope 1 on 1.75 (Approx.)
Original Surface (Approx.)
El 238.93
El 238.48
El 234.10
20" C.I. Inlet Pipe
El 230.1
12" Gunite
SECTION AT INLET PIPE
DANVERS WATER WORKS
DANVERS, MASS.
DRAWINGS SHOWING IMPROVEMENTS TO WILLS HILL RESERVOIR
Slope paving
Step Planks
Slope 1 on 1.75 (Approx.)
2" Track for Run way
Natural Surface
SECTION THROUGH RUNWAY

FIG 2

The original idea of protection by paving was good in theory, but practically it did not work out as planned. One of the reasons, in my opinion, lay in the type of cement used. At that time Portland cement was little used due to lack of knowledge and excessive costs. Rosendale cement was employed, and while this sets quickly and can be used easily on slopes, it did not have the strength for the severe service to which it was put. It cracked, crumbled and went to pieces where it was exposed. Where it was protected by the filling and riprap it was still in good shape and quite firm, so much so, that there were only a few places that needed patching.

Relining Operations

On July 29, 1937 the Commissioners voted to rebuild the reservoir and on July 30, 1937 work started. The reservoir is about 140 ft. higher than the main street and is reached in a climb of 1500 ft. The grade, therefore, is quite steep, particularly the first 700 ft. The road, which was originally used for the construction of the reservoir was in terrible shape. Hence the first four days were taken up by removing large boulders with a tractor and the filling in the road with rock and gravel.

On July 30, we actually started work on the reservoir. We decided that to facilitate the removal of some 2200 yds. of rock and filling we would cut a notch through the side of the reservoir so that we could drive in and out with trucks, thus making the removal of this material an easy matter. At noon of the second day we had made the cut through and built a ramp on the inside to drive down into the reservoir. On the third day we started with a crew of about thirty men to remove the rock and fill, to level it off outside of the reservoir and to construct a temporary structure for an office and storage building for cement and tools. It was several days after this start was made before the method of relining the reservoir was settled upon. After receiving the report of the Portland Cement Association field engineer, and more especially a letter from Mr. Good, Superintendent of the Cambridge Water Works expressing his entire satisfaction of the Gunite job done on his 40-m.g. reservoir ten years previously, we decided to Gunite our reservoir.

We signed a contract with the National Gunite Contracting Company of Boston on August 23, 1937. It was our job to remove all of the rip-rap and fill and thoroughly to clean the reservoir in preparation of applying the Gunite. It was the Contractor's job to furnish all of the material and reline the reservoir.

The following is a copy of the contract and the guarantee:

NATIONAL GUNITE CONTRACTING CO.
82 West Dedham Street
Boston, Mass.
August 10, 1937.
PROPOSAL

Danvers Water Board
Danvers, Mass.

Att: Mr. Roger W. Esty, Superintendent
Sub. Gunite Lining of Wills Hill, Reservoir, Middleton

Gentlemen:

We are pleased to submit our proposition in duplicate covering the Gunite lining of the above mentioned reservoir in accordance with the following.

Scope of Work:

The work to be done involves the lining with reinforced Gunite of the entire inner surface of the reservoir, top of wall and 12 in. down on the outer face of same, the depth of Gunite averaging about 2¼ in. The depth may vary from a minimum of 1½ in. above the most projecting points of stone to as much as 2½ in. to 3 in. in the greater depressions and, according to our figures, should average about 2¼ in. Although it is intended to follow the general contour of the present stone masonry surface, it will be necessary to apply variable depths as noted in order that the finished Gunite surface will present a much more uniform appearance than now exists.

Specifications:

Prior to our entrance upon the work, the Water Board will have removed all loose mortar, earth and other débris from the basin and will have thoroughly washed down the surface of the masonry to be protected with Gunite. Our operations will continue as follows:

1. Lay reinforcing mesh style 4 in. by 4 in. No. 6 by No. 6 electrically welded galvanized fabric, ends and sides of sheets lapping by 4 in. and tied to each other at approximately 18-in. to 24-in. intervals with standard loop wire ties.

2. Prior to application of Gunite, thoroughly water and air blast surfaces to receive Gunite coating.

3. Gunite shall be premixed in the proportions of one part of standard Portland cement and three and one-half parts of clean, sharp and well graded sand. This shall be applied in a single coat. The bottom will in all probability be completed first, following which Gunite application shall be made on the slopes.

4. While shooting is being done, the nozzleman's assistant shall hold the mesh in position at about the center of the Gunite section. Shooting shall proceed in such a way that where possible all rebound shall be shot on to finished work from which it shall be scraped,

collected in piles and removed from the reservoir. Gunite shall be left with a natural cement-gun finish.

Gunite shall be rounded over the corners of the wall.

5. At the end of shooting period, Gunite shall be brought to a feather edge and screeded or roughened for proper bonding with the succeeding coat.

6. Gunite shall be kept moist by means of sprinkling with a hose or other suitable method for a period of four days after being shot. This sprinkling shall be carried on by the Water Board at its expense on that portion of the lining completed last, after our forces have left the job.

Conditions.

In making up our figures, we have assumed the following conditions under which it is mutually agreed the work will be conducted.

We will furnish all equipment, labor and materials needed for the work, except as noted below.

You will furnish the following free of cost to us at the site of the work.

1. Roadway from main highway to reservoir maintained in good condition during the progress of our work.

2. Water to be pumped from your tank located at present at the reservoir, in sufficient volume for hydration, water cooling of our equipment and sprinkling of reservoir.

3. Use of your hoist and car equipment for removing rebound sand from the basin.

4. Facilities which will permit us to carry on our work from beginning to end without interruption by other trades or operations.

Price.

Our price for this work is the sum of $8550.00.

CONDITIONS

1. It is agreed that we shall be permitted to prosecute our work without interruption. If it be delayed at any time by any act or neglect of the owner or the owner's representatives or employees, or any other contractor employed by the owner, or any changes ordered in the work, then we shall be reimbursed for our actual additional expense or damage, including loss of use of equipment caused by said delay unless other arrangements have been made in writing.

2. The price herein quoted does not contemplate doing any portion of this work during freezing weather unless otherwise noted in this proposal. If any work is performed during freezing weather, you are to provide all labor and materials in connection with the heating and protection of the work and materials, and you are also to reimburse us for the additional cost of winter operations.

3. It is understood that you are to furnish us, free of charge, all necessary permits; artificial lighting if required; free access to

the site of the work and sufficient working space to enable us to properly execute this work; necessary clean water piped to within 50 ft. of our cement-gun setups and all flagmen and tickler service.

4. If this proposal covers structural steel encasement in bridges where reinforcing mesh is specified over the tops of beams or other members which carry the deck slab, then this mesh shall be furnished and placed by you at your expense. Our price, unless otherwise stated, includes only the mesh located wholly within the GUNITE section.

5. We are to have the privilege of sub-letting such portions of this work as we believe advisable.

6. Execution of the work covered by this proposal is contingent upon strikes, fires, accidents, delays of carriers, delays in delivery of material, wars, or other causes unavoidable or beyond our reasonable control.

7. We will carry compensation and public liability insurance on men whose names appear on our payroll but will in no way be responsible for the actions of or accept any liability occasioned by employees of others.

8. This proposal is based upon present prices and present conditions, and is for acceptance within days; it is further based upon all labor being open shop.

9. Payments shall be made by you to us on or about the 10th of each month for 90% of the work done the previous month, final and full payment to be made within fifteen days of completion of our work and on presentation of our invoice.

10. We have not included the cost of surety or other bonds in our figures. If any is required, the cost thereof shall be paid by you.

11. This is the entire agreement and covers all of the work to be done under this proposal, and there are no prior representations, either verbal or written outside of this proposal or contract. Any subsequent modifications or changes must be in writing and signed by an authorized agent of this firm.

12. The return of one copy of this proposal, properly signed, will constitute a contract if same was originally signed by an officer of this company. It not, two copies must be returned for the signature of an officer, after which one signed copy will be returned to you for your files.

13. By your signature to this agreement, you declare yourself to be a trustee of the funds to be received by you in the payment of the work to be performed and materials to be furnished by us in performance of this contract.

Accepted August 23, 1937.

"Guy T. Creese"
"Joseph M. Whitter"
"David H. F. Kuell, Jr."
Danvers Board of
Water Commissioners

National Gunite Contracting Co.
By "A. C. Linberg"
Vice-Pres.

NATIONAL GUNITE CONTRACTING CO.
82 West Dedham Street
Boston, Mass.
August 10, 1937.

Danvers Water Board
Danvers, Mass.

Att: Mr. Roger W. Esty, Supt.

Gentlemen:

We are enclosing duplicate copies of proposal covering the lining of Wills Hill Reservoir.

Final total areas computed as a result of information secured from Mr. Esty on the 9th of this amount have increased the footage by 2292 sq. ft., thus increasing the price of the amount quoted instead of $7920.00 submitted by telephone several weeks ago.

In view of the statement by Mr. Esty that your Board intends to award us this contract, we are today ordering the necessary reinforcing mesh in order that there will be no delay covering the delivery of same when the Gunite work is ready to proceed.

Thanking you for this contract, we remain,

Very truly yours,

NATIONAL GUNITE CONTRACTING CO.
"A. C. Linberg"
Vice-Pres.

NATIONAL GUNITE CONTRACTING CO.
82 West Dedham Street
Boston, Mass.
August 18, 1937.

Danvers Water Board
Danvers, Mass.

Att: Mr. Roger W. Esty, Superintendent
Sub: Guarantee

Gentlemen:

With reference to guaranteeing the Gunite lining we plan on applying to the Wills Hill Reservoir as covered in our proposal of August 10th, we wish to submit the following.

In checking with authorities on this subject, we find that the minimum leakage most commonly permitted must not exceed 2% of the volume per 24 hrs. Other guarantees vary from a minimum of ½ in. to ⅞ in. loss in depth for the same period of time. In your particular case, 2/10 of 1% will closely approximate the ½ in. minimum depth referred to. We, therefore, will guarantee that our lining will not permit of leakage in excess of 2/10 of 1% of the volume per

24 hours, and, on the basis of leakage records in other reservoirs that have been lined with reinforced Gunite, we doubt very much that the water loss will be sufficient to measure.

Trusting this is satisfactory, We remain,

Yours very truly,

NATIONAL GUNITE CONTRACTING CO.
"A. C. Linberg"
Vice-Pres.

Perhaps a word of explanation of what Gunite is and its advantages should be given so that those who are unfamiliar with it will have a better understanding of it, before going into the details of the work.

What is Gunite? It is gunned concrete. "Gunite is a mixture of cement, sand and water applied under air pressure. It differs from ordinary concrete with the same ingredients, in its method of application; concrete is *poured* into place, or in the form of mortar it is applied by a trowel—Gunite is *shot* into place under pressure.

What are the advantages of Gunite?

1. It has a strength two to three times that of average concrete.
2. It possesses a density that makes of it a waterproofing medium.
3. It gives perfect protection to steel against rusting.
4. It is proof against the action of salt water and frost.
5. Its resistance to alkalis and acids is relatively high.

How is it applied? In order to permit pressure application, a device called a Cement-gun is used (See Figure 3). A sketch, Figure 4, outlines its construction. To operate, a supply of compressed air must be brought to the Cement-gun. Within it are two chambers, the upper A and the lower B. Pre-mixed sand and cement in a dry state of the required proportions are placed in the upper chamber, bell valve C is closed and air is then delivered to this chamber. The pressure in the upper chamber almost immediately reaches the same pressure as that in the lower working chamber where the pressure is uniformly maintained at all times. Because of the equalizing of the pressure in the two chambers the lower bell valve D opens, thus permitting the material to drop into the lower chamber.

Feed wheel E, driven by air motor K and revolving about feed-wheel shaft F, delivers material uniformly to outlet valve G and out through the material hose H to the nozzle.

When the upper chamber becomes empty, bell valve D is closed and the air pressure is released from chamber A, causing bell valve

FIG. 3 — CEMENT GUN

C to drop, which permits the loading operation into chamber A to be repeated. All the while, material is permitted to pass out continuously and uniformly from the lower chamber.

Referring now to Figure 5 showing the nozzle, hose H contains the dry cement and sand carried from the gun to the nozzle by the air pressure. A second hose, L, carries to the nozzle a supply of water, at a pressure somewhat higher than that obtaining in the material hose. This water is driven into the stream of dry material through a water ring fitted within the body of the nozzle, saturating the dry material, which continues on through the nozzle into place on the structure.

The pressures generally used are from 35 to 60 lb. per sq. in. which produces a compact, dense material far stronger than ordinary concrete. Not alone is the strength and density of Gunite due to this high pressure, but primarily to the water cement ratio which is maintained at a minimum at the nozzle by valve control in the hands of the operator. (Note Figure 5.) Should too much water be used, the

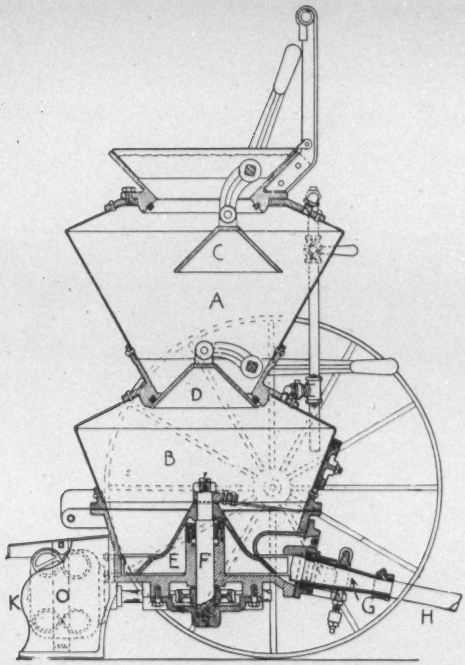

FIG. 4 — SECTION THROUGH CEMENT GUN

materials will wash away, or should there be too little water, the materials cannot adhere. Thus a minimum water cement ratio becomes part of the nature of Gunite, an absolute necessity.

The following is a description of the "Advantages of Gunite" relative to strength, waterproofness, and proper steel protection.

A. Strength

In explanation of the reason for the greater strength of Gunite (gunned concrete) over *poured* concrete or mortar, it is necessary to analyze the placing action of the two.

The Cement-gun feeds a mixture of dry cement and sand uniformly and evenly into a stream of compressed air passing through a hose. When the dry material reaches the nozzle, the water is added under the operator's control in such quantity as is required for the best possible hydration, or about 11 to 12%. Poured concrete on the other hand is of necessity mixed and deposited with a water content

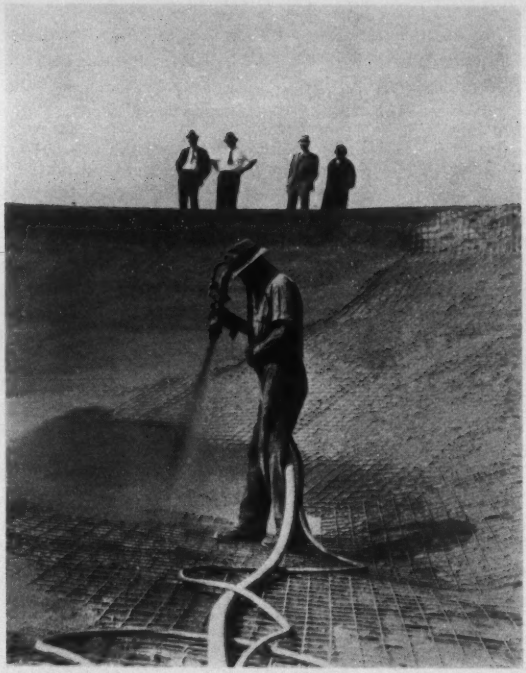

FIG. 5 — GUNITING NOZZLE IN OPERATION

of 25% or more. Since the excess water evaporates leaving voids, it is clear that that concrete which can be placed with minimum excess water will be most dense and therefore have greatest strength. Gunite concrete easily meets this requirement of low water cement ratio better by far than poured concrete.

Not only is the density due to this water cement ratio, but in addition the compacting action of the aggregate traveling at high speed from the nozzle assists appreciably. This action results in an automatic segregation which fixes the proportion of cement to sand. Thus, should a grain of sand strike into a matrix of cement it will embed itself and adhere. Should it strike another grain not covered with cement it will rebound and be lost. The blow however has served to further drive the embedded grain deeper and more solidly into the mass, bringing greater compacting. Air pockets or bubbles cannot form under such conditions.

Ordinary concrete of 1-2-4 mix averages 2,000 to 3,000 lb.

strength. Where used as a mortar with one part cement, four parts sand and no stone, it averages 1,500 to 2,000 lbs. Gunite mixed in the proportions of 1-4 has a strength ranging from 5,000 to 7,000 lbs.

B. Waterproofness

It follows naturally that the more dense a material is, the more impermeable it is. Ordinary concrete if fairly thick has sufficient density to be more or less waterproof under low heads of water, whereas with Gunite very thin sections have withstood water heads measured in hundreds of feet. An example of this is the test made by the University of California and described in the August, 1917, Proceedings of the American Society of Civil Engineers. Here a 1-in. thick sample of Gunite was subjected to a head of 1,610 ft. for two hours and thirty minutes without indication of moisture, whereupon the head was increased gradually to 3,400 ft. when the specimen broke. On examination of the sample, it was found that moisture had penetrated to a depth of only 5/8 in.

C. Steel Protection

Much depends on whether Gunite gives perfect protection to steel embedded in it against rust action. Unless this protection is attained the rusting steel will expand and rupture the covering, requiring consequent repairs.

When ordinary concrete is exposed to air it is necessary in order to prevent oxidation of steel to cover it with a substantial thickness of at least 2 in. Where the concrete is under water or alternately wet and dry between high and low water, this thickness needs to be greatly increased.

Gunite coverings down even to 1/4-in. thickness have never, so far as we know, permitted the embedded steel to rust whether in air, in water, or alternately wet and dry. This remarkable property is due to the density and waterproofness of Gunite and to the coating of pure cement which envelops the steel before any Gunite will adhere to it.

Getting back to the actual work, the job really started on July 30, and was completed October 2. It took 55 days, three days were lost on account of rain. It was estimated to take 90 days, but due to good weather during the removal of the material and the exceptional fine crew of men, we were far ahead of schedule.

We estimated that about 300 cu. yd. of stone were to be removed from the slope. This was completed in eight days. Most of the time there were two trucks hauling rocks. It would have taken one truck 13 days or 104 hours. They hauled out 267 loads, from 20 to 26 loads in an 8-hour day with 6 men loading to a truck with a driver. On August 10, all of the rock was out. As there were 267 loads of rock and figuring 1¾ cu. yd. to a load, the total yardage of rock

removed was therefore estimated to be 467.25 cu. yd. It cost for labor and trucking to remove and level them off $483.30.

The filling which averaged about 30 in. in depth on the upper slope had all been hauled out on August 27. It took 24 days from start to finish, starting on August 4. Sometimes one truck and at other times three trucks were employed. They would haul from 24 to 31 loads per 8-hour day, with six men loading and one driver. Two men spread all of the filling and rocks outside of the reservoir in the dumping area. We hauled out 982 loads, and estimating 1¾ cu. yd. to a truck, we moved 1718.50 cu. yd. Labor, trucking, and spreading, cost $1,750.57.

You can readily see that it cost a little over $1.00 per cubic yard to remove the rock and gravel and clean up the reservoir in good shape with the exception of the washing. This washing cost $71.93 for labor exclusive of the compressor which operated an old boiler feed pump, that was salvaged when the steam pumping plant was discontinued. This pump was very effective, in fact it was our real solution of washing thoroughly the clayey material from the masonry work. We tapped the main feed pipe outside of the reservoir and ran a 2-in. pipe to the pump, then a 2-in. pipe to the top of the embankment. We extended a 2-in. pipe about one half the distance around the reservoir with four 1½-in. risers for our 1½-in. hose.

We had a pressure guage at the highest elevation, and we kept the pressure to about 90 lbs. per sq. in. when we were washing. We would extend our hose out 50 to 150 ft. with a ½-in. nozzle on the end. At times it was all that one man wanted to do to hold the nozzle. We used two men for washing, one to hold the nozzle and the other to move the hose, alternating each half hour. The water was chlorinated and the entire structure was washed several times.

As has been said, our first move in cleaning out the reservoir was to cut a notch through the embankment to get the trucks in and out of the reservoir. The rocks were removed first. A loading platform was placed against the lower slope and the rocks were either rolled in or carried in. About 11,200 square feet of area of rock had to be removed from the slope. It was a rip-rap job, and the depth of rock was from 16 to 18-in. As previously stated these rocks were removed in 7 days, two trucks doing most of the work.

After this we were able to back our trucks along the side of the slope, and we hauled out about three-fourths of the area in this manner and then removed what had been the road way or one-quarter of the area. This material, about 30 to 36 in. in depth, was entirely removed by three trucks in 24 days, only one truck being used during the last three days to clean up. Then followed the washing. The base

was in poor shape, that is, some of the surface was smooth and some rough. We broke out the entire surface area with paving breakers and left it in a roughened condition.

Before all of this work was completed enough area had been cleared so that the National Gunite concern moved in and started laying wire on Thursday, September 2, thirteen days ahead of schedule. We had previously informed them that we would not be ready until September 15.

The old masonry slope did not go to the top of the embankment. To make a good looking job and to prevent rain water from washing in and weeds from growing on the upper slope we extended the wall up perpendicularly for about 4 ft. with a width of 18 in. at the base and 12 in. at the top, the top 6 in. rising above the ground level. This wall ran for 558 ft. 6 in. around the reservoir, and its costs for labor and material was $1,218.27. Use of equipment, a cement mixer and a tractor which belonged to us is not included in this figure. We used a one-bag mixer, and the tractor was employed to haul up the rocks and cement to the top of the embankment. This equipment kept about 15 men going, and we averaged about 60 ft. of completed wall per day, with an average cost of about $2.20 per ft.

The wire was hauled at first to the level just above the first slope. Later we found it easier to haul the rolls of wire with the tractor on a drag to the top of the embankment. These rolls were then set up on two horses with a pipe through the center of the roll of wire. Two men took the end and slowly pulled it down the slopes with two men on top unrolling it from the reel. The rolls weighed about 62 lb. per 100 sq. ft., and each roll contained about 1200 sq. ft. of wire mesh in 4-in. squares, the gauge being No. 6 by No. 6 galvanized electrically welded fabric. A total wire area of 30,770 sq. ft. was used in covering 29,742 sq. ft. of reservoir area.

The wire was so laid that the rolls overlapped 4 in. or the width of one square. It was bound together with special wire at about 12 in. to 18 in. intervals. In order to make the wire lie level and close to the original masonry, holes were drilled to receive a special bolt to hold the wire in place. After the wire had been laid and fastened securely in place, we were prepared to start shooting the Gunite.

In our set up, the contractor had three compressors with a total capacity of about 550 cu. ft. Two were only necessary, but when the material was being forced to the far corner of the reservoir, it was helpful to have the third machine in operation.

Edison cement was used as it is considered to be a little finer in texture and tends to form a lining of greater density. The sand and cement were mixed dry in a regular mixing machine and were

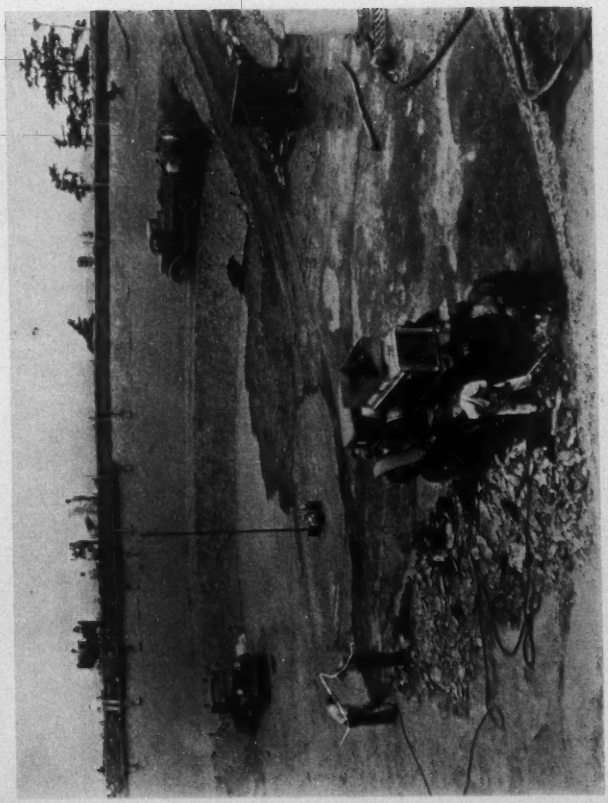

FIG. 6.—PREPARING RESERVOIR FOR GUNITING OPERATIONS

then dumped on to a platform. The mixture was then shoveled through a screen and drawn with a hoe as needed into the Gunite machine by the operators. It was figured out when the job was completed that the mixture was one part cement and 3.56 parts of sand.

The cement and sand were forced by air pressure through the hose to the nozzle where it was mixed with water from another hose line under pressure. The explanation on the machine and operation previously given, tells completely how the cement mixture is driven into place, and the contract tells explicitly what the depth of cement should be.

About one-half hour after the process was completed the surface was scraped with a hoe, smoothing the surface and at the same time collecting the rebound into piles. Later this was carried away. The surface was sprayed with water for the next four days as often as weather conditions warranted. The final surface produced is reasonably level and smooth. The top surface of the ring wall was scraped with a trowel.

When the Gunite has had sufficient time to set and harden, it resounds like a piece of granite if struck with a hammer. It is very dense, firm and hard and apparently is as near leak proof as anything can be made with cement.

On Saturday October 2, 1937 the reservoir was completed even to the final grading and the removal of all of the equipment and buildings.

The water was turned on September 29, at 8:27 A.M., and the reservoir was filled that evening at 9:27 P.M. The following tabulation gives the amount of water stored for each rise of one foot in elevation, except for the top one-half foot.

Rise in water Surface-feet	Storage-gallons	Rise in water Surface-feet	Storage-gallons
1	48,000	9	133,000
2	65,000	10	142,000
3	68,000	11	147,000
4	79,000	12	160,000
5	80,000	13	169,000
6	105,000	14	172,000
7	120,000	14½*	72,000
8	129,000		
		Total	1,689,000

Leakage tests were made on two consecutive nights by filling the reservoir to overflow level. Each morning the water surface was flush with the overflow. If there was any drop, it was too small to be

*Overflow.

measured. The tightness apparently is 100%. A supposed spring, which for years supplied drinking water for a herd of cattle on the side of the hill, has completely dried up.

We are well pleased with the results obtained, but time alone will tell how worth-while this type of construction really is.

Some of the costs and quantities of construction follow:

Cost of Material	$9,709.73
Cost of Labor	5,200.89
Total	$14,910.62

Use of equipment owned by the Department is not included. If this is placed on a hiring price basis, we feel that the value of the equipment was about $2,000. Cost of supervisions can be estimated at $530.

Estimated cost	$17,441
Actual working time	53 days
Cement used on Gunite work	2,069 bags
Sand used on Gunite work	275 cu. yd.
Wire used	30,770 sq. ft.
Actual area covered	29,742 sq. ft.
Average depth of Gunite	2¼ in.
Extreme depths of Gunite	1½ to 4 in.
Mixture	1 part cement; 3.5 parts sand
Wire	4 in. by 4 in. No. 6 by No. 6
Rip-rap removed	467 cu. yd.
Fill removed	1,718 cu. yd.
Total rock and earth removed	2,185 cu. yd.

We are extremely grateful for and pleased with the manner in which the work was carried on to successful completion under the able direction and supervision of Mr. Andrew C. Linberg, Vice President of the National Gunite Contracting Co. He had a very able and efficient organization, both in personnel and equipment.

SUBMERGED RIVER CROSSING AT AUGUSTA, MAINE

BY S. S. ANTHONY*

[*Read September 21, 1937.*]

The outstanding event of the year 1936 at Augusta, Me., was the double flood of the Kennebec River on March 13 and 19, when the Kennebec River reached the highest flow on record. While on March 13 the discharge of the river was not as great as on March 19, the water level was higher by approximately 3 ft., due to the jamming of ice of great thickness in the numerous narrow channels between Augusta and the junction of the Kennebec and the Androscoggin rivers at Merrymeeting Bay.

With a snowfall of unusual depth and undiminished by thaws, on March 11 and 12, a total rainfall of nearly 7 in. occurred, reducing the snow blanket to almost nothing and swelling all streams to many times their normal flow.

The operating department of the Augusta Water District felt that precautions should be taken to insure a continuous supply of water to the East side of the city, where are located the Federal, State and City hospitals, as well as a large proportion of the city's inhabitants. Since all water for these customers was carried on bridges spanning the river, the East side would suffer a shortage or be completely cut off from a supply, in case of failure of one or more of these bridges.

Plans were accordingly made to provide at least a temporary service by means of cables stretched between high buildings on either side, by means of which it was proposed to suspend as many lines of fire hose as possible to convey water across in quantities at least sufficient for domestic purposes. Happily, these cables were not needed, as the three bridges withstood a terrific battering and emerged practically unscathed from both floods.

This experience, however, emphasized the need of a pipe line across the river entirely independent of bridges, a need which was recognized as long ago as 1905, when the first surveys were made for such a crossing. Again in 1912, other routes were surveyed and abandoned due to what was then considered excessive cost. A recently abandoned railroad bridge was purchased by the District and a 16-in. pipe was laid upon it, connected on each side of the river to 16-in. lines in Water Street and Willow Street.

In May, the writer was instructed to make surveys and tentative plans for a submerged pipe line connecting the water mains on either

*Engineer and Superintendent, Augusta, Me.

shore. These surveys were accordingly made and the location selected, from a point in Water Street near the railroad bridges, directly across to a point in Willow Street, near Myrtle Street. This location was selected because it was very nearly the narrowest part of the river, and because pipes of the same size, namely 16-in., were already in place and available for connection.

Detailed plans of the proposed construction were made and submitted to Metcalf & Eddy for review and suggestion. The plans as drawn were approved by them, and by vote of the Trustees in June, the writer was authorized to proceed with construction.

Plans and specifications were submitted to three concerns with extensive experience in submarine construction, for estimates and bids. Due to the uncertain character of the work to be done and the difficulty in making exact estimates of cost, the several concerns were invited to submit bids only upon the fee they would charge for supervising construction, with the District bearing the expenses, whatever they might be.

The bids for supervision fee were as follows:

R. H. Houston, Inc., Portland, Me.	$3,000
Sanders Engineering Co., Portland, Me.	3,500
Merritt Chapman & Scott Corp., New London, Conn.	5,000

Estimates of cost were about $38,000 in each case, exclusive of land purchases, pipe costs and shore connections.

No arrangement was made at the time with any of the three bidders for supervision of the project, the Trustees of the District deciding that the amount of the proposed fee could well be expended on construction and the work done under the supervision of the District's engineer and an experienced foreman to be engaged for the job.

Plans had been made to commence operations on the West side of the river and proceed with the pipe laying in an Easterly direction. The advantages of this scheme were that the deepest part of the river channel would be passed during the summer months when water levels could be expected to be at their lowest point. It was also planned to commence not later than July 1, 1936.

Due to difficulties in adjusting the price to be paid to the Maine Central Railroad Company for land necessary on the West side, with consequent delay, it was decided to begin operations at once on the East side, trusting that an agreement might be reached before it was necessary to work on railroad property. The Gannett Publishing Company, owners of the property on the East side gave a right of way without charge for as much land as was needed providing use of the land was not restricted in the future.

Accordingly, on July 22, materials for the cofferdam having ar-

rived on the job, work was started and proceeded without serious delay until September 14 when the last length of pipe was laid in the Easterly section of the cofferdam in the approximate center of the river. A start was then made on dismantling the cofferdam, leaving a 60-ft. island for a starting point to proceed with the next section of approximately 150 feet. See Figures 1 and 2.

On October 2, the new section previously constructed on the East side in shallow water, was set in position late in the afternoon and guyed to the Water District bridge. The current in the river was strong enough, however, to cause the guys to break, allowing the skeleton crib to float down river to a point behind the Colonial Theater, where remaining guys held it from further loss. On the next day, the crib was cut in half lengthwise and the upstream half placed, loaded with rock ballast and guyed with larger cables. The downstream half was later placed in position and work was started on the construction of the box coffers, to be filled with clay and gravel for water tightness.

On October 18, after several days of heavy rainfall, the river rose to nearly flood stage and overturned the partially completed cofferdam so that work was suspended until the river returned to more nearly normal flow. See Figure 3. Additional heavy equipment was secured, a large scow, derrick and hoisting engine, and work resumed clearing wreckage on October 31. Early in November it was decided to engage the services of Sanders Engineering Co. to supervise the completion of the project, and on November 9, their superintendent arrived and took charge.

From that date on, work was carried on without cessation, day and night, construction proceeding at a rapid pace. With the cofferdam successfully pumped out, drilling operations commenced on December 7. On December 12, the river again rose sufficiently to flood the cofferdam and suspend operations until December 17 when the water was again pumped out and more pipe laid on December 19 and 20.

Predictions of river authorities on that date stated that due to heavy rains at the headwaters and the frozen condition of the ground, a water stage equal to the normal spring runoff was to be expected within a few hours. These predictions proved correct and on the night of December 20 work was suspended and the cofferdam allowed to fill to reduce the strain of the rapidly rising water. See Figure 3.

Late in the afternoon of December 21, ice more than 12 in. thick began to move down river, and as the water level was above the steel piling forming the cofferdam, the space inside was soon full of solid and slush ice. The river remaining at a high point, it was

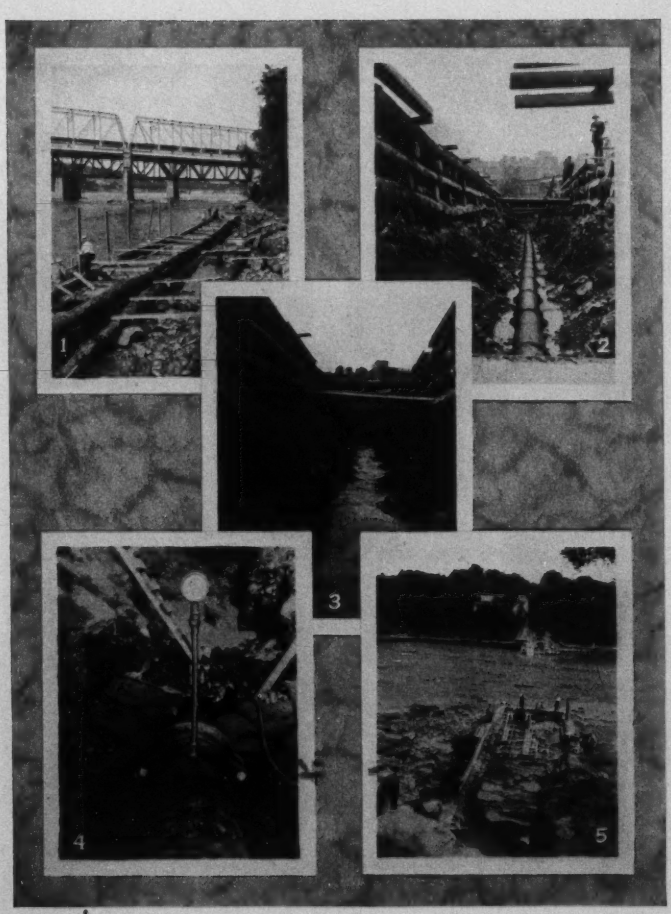

FIGURE 1

CONSTRUCTION OF THE KENNEBEC RIVER PIPELINE—1. Constructing first crib—East Side. 2. First Section of pipe—East Side. 3. Completed trench, ready for pipe—East Side. 4. Testing first section of pipe. 5. Start of operations on West Side.

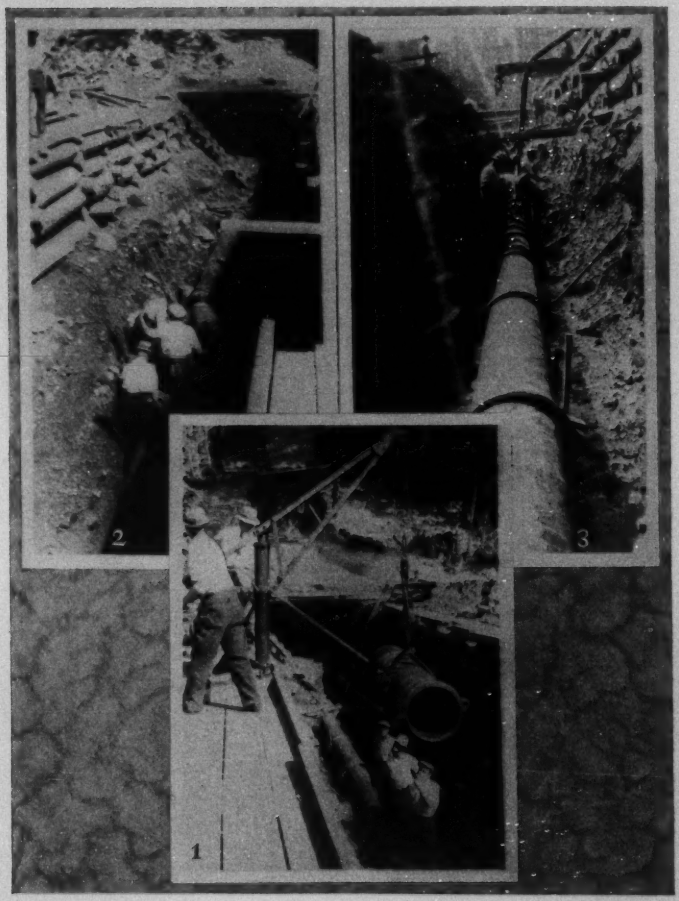

FIGURE 2

CONSTRUCTION OF THE KENNEBEC RIVER PIPELINE—1. Lowering pipe into trench. 2. Joining lengths of pipe together. 3. Completed section of pipe.

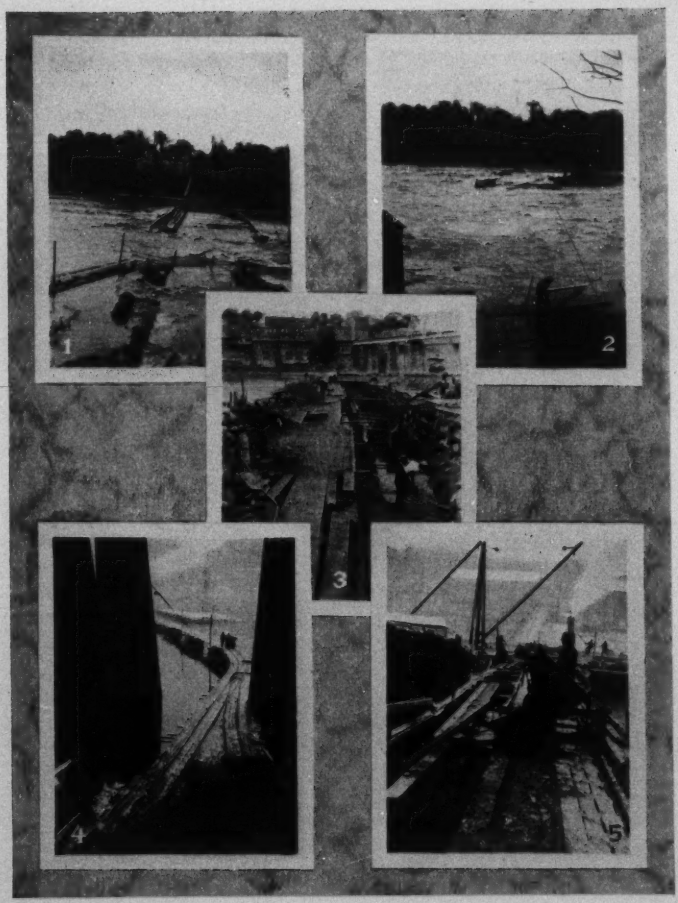

FIGURE 3

CONSTRUCTION OF THE KENNEBEC RIVER PIPELINE—1. Cofferdam damaged by high water on October 18, 1936. 2. Cofferdam submerged by high water on December 20, 1936. 3. Section of pipe completed and being backfilled with gravel and concrete. 4. Railroad track for handling materials on cofferdam. 5. Dump car unloading gravel fill.

impossible to start repairing damage until December 26, 1936, and on January 1, 1937, drilling operations were again resumed in a dry cofferdam. This phase of the work was completed with pipe laid and covered on January 11 when the midstream section of coffer was demolished. Work was started on January 23 on the third and final section, which was completed and dry on February 7, when excavation was started.

A little over a week later the "Imperial Kennebec" again rose and drove us out for three days. After this period, feverish activity until March 1 completed the pipe laying and backfill, and we started dismantling the cofferdam, finishing just in time to get the derrick and equipment off the scow and the scow moored in a cove down river before the river again rose to freshet stage, remaining there for several weeks. On March 19, all work in the river was completed and the pipe line was placed in operation. See Figure 4.

The pipe used is 16-in. Universal, Type T, 250-lb. working pressure, and coated inside with a ¼-in. cement lining which in turn was double coated with tar. The exterior was also double coated with the same material.

After laying each section of from 6 to 20 lengths, the whole line was placed under hydrostatic pressure of 150 lbs. per sq. in. for a time and then tested for leakage for a period of 12 hours at 140-lb. pressure. Leakage at this pressure was measured by a 1-in. domestic meter, with allowable leakage rate at 1 gal. per 24 hours per linear foot of joint. Actual leakage did not exceed 10% of the allowable, except on one occasion when a cracked spigot in the last length laid was discovered. This was removed on the next morning. After a few hours, even this small leakage ceased.

The pipe was laid in a trench excavated in the bottom of the river. Where ledge rock was encountered the minimum cover was 4 ft. and where no ledge appeared within the trench, the minimum cover was 6 ft.

After laying the pipe in a bed of fine gravel, the trench was backfilled with gravel, from which all stones larger than a grapefruit had been removed, up to a point about 1 ft. above the pipe in gravel trench and 1 ft. below the rock surface in ledge trench. A layer of 10 to 12 in. of rich concrete was then laid over the gravel backfill, and the remainder of the trench to the level of the river bottom was filled with large stones and gravel, well bedded together in order to make the bed of the river as nearly uniform as possible.

Extreme care was taken to leave no ridges or hollows in the river bottom, either upstream or downstream from the pipe, to cause scour.

The whole length of the pipe line was 760 ft. of which 640 ft.

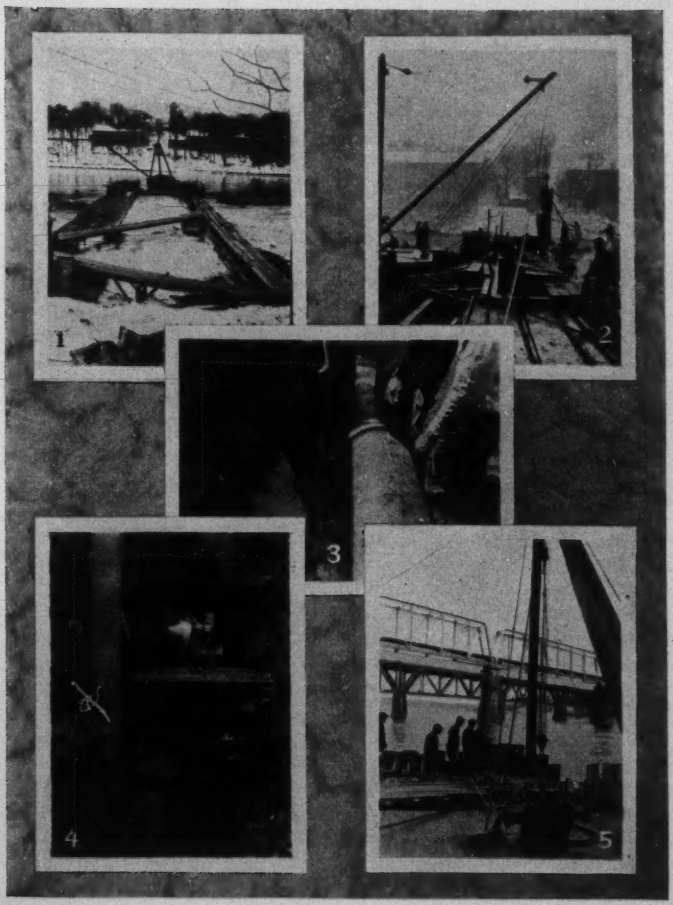

FIGURE 4

CONSTRUCTION OF THE KENNEBEC RIVER PIPELINE—1. General view of last section of cofferdam before pumping. 2. Driving steel sheet piling. 3. Making up joint in pipe line. 4. Typical section of completed pipe line. 5. Pulling steel sheet piling after completion of pipe laying.

were below high-water mark. The cost of the job when completed was approximately $85,000 divided as follows:

Shore structures, dock, offices, storehouses, etc.	$ 1,341.79
Cofferdam	36,680.87
Pumping	8,687.49
Drilling and blasting	4,380.04
Excavation and backfill	8,433.70
Pipe laying	5,123.13
Concrete slab	2,647.86
Cleaning up	2,161.88
General expense	6,702.40
Repairs to cofferdam after flooding 4 times	2,824.84
Land purchases	900.00
Engineering and legal expense	2,754.92
Workmen's compensation insurance	2,408.29
Total	$85,047.21

Approximately $5,000 will be realized from sale of surplus materials and supplies left over from the job, consisting of about 60,000 ft. of 10 by 10 spruce and hemlock timber, cable, small tools and the 16-in. pipe which was retired from service on the old railroad bridge.

COLLECTING WATER BILLS

BY CHARLES W. EASTER*

[*Read September 24, 1937.*]

I am not undertaking to tell any superintendent how to collect water bills for his own departments. My purpose is merely to describe as nearly as possible, how we go about it in Claremont, N. H., a town with a population of about 13,000, 1917 services and annual collection of about $38,000.

In the first place, the Claremont Water Works is entirely separate from any of the other departments of the town. The department consists of three water commissioners, one being elected each year at the annual town meeting. This same board hires the superintendent, and meetings are held only at such times as the board deems advisable, or at the request of the superintendent, who is entrusted with the duty of purchasing all materials and paying and collecting all bills, including making payment of interest and principal on bonds and notes.

The department is about 85 per cent metered, and meters are read each month, though bills in most instances are mailed semi-annually. If the monthly reading shows that an unusual amount of water has been used, a post card is sent to the property owner notifying him of this fact, thereby giving him an opportunity to check up on possible plumbing defects or other causes of waste. If the reading is still high for the next month, another card is sent; but if excess usage continues thereafter, we feel that the customer has been adequately notified and is satisfied that the consumption is legitimate.

Our water bills are mailed semi-annually, in January and July, with the exception of a few monthly bills to a group of larger consumers, including hotels, restaurants and laundries. Although these monthly bills may sometimes run two or three months before payment is made, collections rarely give us trouble.

The minimum charge of our semi-annual bills, together with the excess of the previous six months, is payable in advance, and payment is required on or before March 1 and September 1 respectively. One week before these dates, a notice is published in our local daily paper, stating that all persons not paying their water bills before such dates will receive a shut-off notice. This procedure is usually effective in bringing in the greater part of unpaid bills. The shut-off notice is then sent to each owner who has not paid his water rent. It states definitely that if bills are not paid by the 15th of the month, or arrange-

*Superintendent of Water Works, Claremont, N. H.

ments made to pay them, the department will take steps to turn off the water. This takes care of most of the delinquents, although a few usually wait until the last day of grace before they call and offer to pay in weekly installments. This offer we are glad to accept. Others offer to work out their water rent, and often, even the next water bills also; and, if we have plenty of work, we allow them to do so. Frequently it develops that the man is a good worker, and worthy of retaining as a permanent member of our staff of employees as long as work is available.

On the morning of the 16th of March or September, the foreman is given a list of persons still in arrears, with instruction to visit them and turn off the water if he does not get the money or a promise of a date on which the delinquent customer will pay up. He is seldom forced to shut off the water supply from any of the premises visited, but he usually gets more promises than money at that time. If those who have made these promises do not fulfill them upon the date agreed, I write them a personal letter in longhand, as we have found that a typewritten letter in most cases is ignored. I have found it advisable to vary the tone of these letters and to adapt it as nearly as possible to the persons addressed. In order to strike the right note, it is necessary either to know the addressee personally, or to have investigated him and his circumstances carefully. With some, a harsh letter is required; with others, a more friendly tone produces the best results. In these letters, of whichever type they may be, it is made plain that the bill must be paid by a certain date, or the water will be shut off without further notice. This threat, or promise, is invariably fulfilled; and if water is turned off, we usually get results in an hour or less. We are seldom forced to discontinue service to more than two or three customers, and it is rarely necessary to do so more than once in any individual case. I might say at this point, that we never intend to turn off the water in any home where there is sickness. At the time of closing our books, about January 15 of this year, we had only $7.00 of uncollected semiannual water bills. This amount was paid by August 1, thus completely cleaning up all water bills of 1936, both semiannual and monthly. The only uncollected bills of any kind on our books at present total $15.85; a portion of this amount is for pumping out a cellar, and the balance is for junk sold to a dealer who has since left town. I might add that we have little expectation of ever collecting this sum of $15.85.

We never make a practice of laying a service into a man's cellar unless we feel that he will pay promptly. If he admits that he is unable to do so, we require him to dig his own trench and furnish the pipe or pay us for the same before it is laid.

Other things being equal, we hold to the belief that the most per-

sistent department is the one that gets the money; and while some other departments may, as a result, be forced to go without funds, we feel that our present policy, as far as we ourselves are concerned, has amply justified itself in results.

RATE STRUCTURES

BY THEODORE L. BRISTOL*

[*Read September 24, 1937.*]

There are many rate structures that look similar but are different in their application. For example, some allow combined readings in billing water used by several meters owned by an industrial user or an individual owning a large number of properties; others do not. My own belief and practice is that water used through each meter should be billed separately according to the amount of water used through that particular meter.

When I first entered the water business about 40 years ago, practically all water was sold on flat rates, that is, so much for a sink, washtub, toilet, urinal, sillcock, etc. Our schedule of meter rates was something amazing, for by controlling the amount of water used, a customer could, by drawing a little more water, pay less for it. This is called a jump scale. The schedule was based on the average daily consumption of water per quarter of three months using 75 days in arriving at the daily use, for example:

450 g.p.d.	=	33,750 gal.	@ 30c	= $10.13
500 g.p.d.	=	37,500 gal.	@ 25c	= 9.38
900 g.p.d.	=	67,500 gal.	@ 25c	= 16.88
1000 g.p.d.	=	75,000 gal.	@ 20c	= 15.00
1900 g.p.d.	=	142,500 gal.	@ 20c	= 28.50
2000 g.p.d.	=	150,000 gal.	@ 15c	= 22.50
4900 g.p.d.	=	367,500 gal.	@ 15c	= 55.13
5000 g.p.d.	=	375,000 gal.	@ 12c	= 45.00

As a newcomer in the business, I could see no sense in such rates, so our rates were changed to the present way of billing, that is, so much for the first block of so many cubic feet and so on in blocks. This is called a sliding scale.

Everyone seemed to have copied the other fellow on flat and meter rates and regardless of the cost of operation, as the rates were more or less alike. In the beginning of the water business, there was no simple, cheap and approximately accurate way of measuring water. Earliest rates were guessed, and later rates were based on what other nearby water works charged.

A schedule of flat rates is practically an invitation to the customer to waste water. Small leaks are constant and the customer does not realize to what they amount in the aggregate. Efficient operation

*President, The Ansonia Water Co., Ansonia, Conn.

demands metering. There is no equitable basis of determining a flat rate, as one consumer may use or waste very little water and another many times as much. Frequent inspection, many think, will prevent waste, but in my opinion, it does not prevent excessive use.

There were differences in arriving at flat rates. Some based the base rate on the value of the property served, some on the number of persons served in the house, some on the street frontage, and some on the number of fixtures supplying water; others covered only the first sink which was a family charge, first toilets, baths and sillcocks. Mealers and roomers as well as the number of stories and rooms in the houses were counted. Very seldom were rate schedules formulated by scientific study. Most laymen, water works men and city officials determined the rates on policy.

It has been stated that the adoption and approval of rates, when based on complete engineering and business analysis of the water business, would meet with only slight opposition. I question whether this statement is true, as there is always a group that will kick if rates are raised. The statement, however, as a general principle, ought to be true. And by proper publicity of the facts, gradually released, it should be much easier to get increased rates when desired.

Comparison of rates of one city with another are unfair, because of the difference in the topography of watersheds, the cost of building reservoirs and installing the distribution system. Collection of water may be expensive in one community and not in another. Excavation may be difficult in one place and not in another. Assessment on main extensions which are capital contributions are made in some cases and not in others. In comparing rates of different water works, as far as they are based on expenses, there is a great difference between different departments since costs depend upon treatment of water, pumping, service given—like investigation of leaks and complaints—protection of watershed by furnishing leak-proof outdoor toilets and necessary cleaning and other pollution abatement, such as purchase of farms, moving or taking down buildings, purchase of land to prevent future pollution, reforestation and patrolling. Some municipal water works bills are paid to other departments thus saving expenses to the water works. Taxation or lack of it also makes for considerable variation in rates required.

In studying the history of water rate structures, I found that a Committee on Meter Rates of this Association reported on September 13, 1905,[1] a frontage assessment method and a multiple minimum rate method. The first was based on street frontage, and the second on minimum rates for different kinds of fixtures in use. For example one family on a metered service would pay a yearly mini-

[1]This Journal, 19, No. 3.

mum of $6.00 for a faucet, $5.00 for a water closet, $4.00 for a bathtub and $5.00 for a hose. No further charges were to be made until the amount of water used in any quarter exceeded, at meter rates, the amount of the minimum charge paid for that quarter. The report also suggested the desirability of the general use of 100 cubic feet as a unit of measurement rather than 1,000 gallons. Meter rates were suggested as follows for each consumer per annum.

10,000 cu. ft. or less annually—25c per 100 cu. ft.
More than 10,000 and less than 20,000 cu. ft.—20c per 100 cu. ft.
More than 20,000 and less than 50,000 cu. ft.—15c per 100 cu. ft.

Any customer paying $20.00 per annum in minimum charges was to be entitled to use of water at meter rates regardless of the fixtures in use.

Charles W. Sherman in a discussion of the Committee's report, brought out the desirability of following the method of what is now known as block rates on a sliding scale. The first block of say 10,000 cu. ft. at a high rate, the next block at a lower rate, etc.; the higher rate applying even in case of a large consumer to the first fixed quantity of water. Someone else suggested that rates should be made corresponding to the use; that the householders should pay a higher rate than manufacturers who use water for industrial purposes in large quantities.

In September, 1914, the Committee on Meter Rates made another report[2] in which it did not recommend the minimum charge based on fixtures or frontage, but advocated a service charge of which the principal part covered unregistered water. The report also discussed whether the measurement should be made in gallons or cubic feet, and recommended three divisions of the sliding scale, as follows:

First 10,000 cubic feet per quarter.
Second—Next 90,000 cubic feet per quarter.
Third—All over 100,000 cubic feet per quarter

In February, 1916, this Committee made another report suggesting a service charge and the same three blocks for rates, calling the first block the *domestic* rate, the next block the *intermediate* rate, and the third block the *manufacturing* rate. The prices were to be fixed according to local conditions. It was recommended that the domestic and manufacturing rates be fixed first; that the manufacturing rate should seldom be less than half the domestic rate; and that the intermediate rate be half way between the other two.

A motion was made that this report be accepted and that the form for making meter rates recommended by the Committee be adopted as the Standard of the Association. This motion was not carried; its dis-

[2]This Journal, **28**, No. 3.

cussion was lengthy.[3] In November, 1916,[4] the Committee on Meter Rates made its final report and its recommendations were adopted.

It is the duty of every water works administration to endeavor to earn a fair return on the fair value of the property dedicated to public use. The rate structure is determined from the fair return plus all expenses including taxes, depreciation, operation, maintenance, etc. The steps necessary to find a fair return are:

1. To ascertain a value of the physical property including water rights, rights-of-way, pollution abatement, etc.,
2. To determine the working capital, cash and supplies.
3. To find the going value, which is the development cost, the intangible assets or the added value which a going concern has over a concern which is just complete but not going.

After these steps have been taken, the next question is what rate of interest it would be fair to get on fair value to obtain a fair return. By adding together fair return, taxes, depreciation and all other expenses, the gross revenue that should be earned is indicated. The sources of this revenue are:

1. Miscellaneous revenue such as rents from lands, buildings, wood, appliances, profit on materials, etc.
2. Fire protection revenue which should be the actual cost of maintaining hydrants and the annual return on the excess cost of building a distribution system to provide fire protection instead of a system for domestic, commercial and industrial use only.
3. General water service revenue such as domestic, commercial and industrial.

The problem is to devise a rate structure that will distribute the burden equitably. This rate structure must be productive of earnings large enough to provide credit so that money for extensions and enlargements may be procured on favorable terms.

After determining the gross revenue required, subtract the miscellaneous revenue from this and then decide how this result shall be divided for fire protection and general use. An analysis of what proportion of the property is devoted to fire protection will show how much of the revenue should come from this source. Fire protection is usually provided by the installation of much larger mains than ordinary use requires.

In a paper entitled "Reasonable Return for Fire Hydrant Service," by Metcalf, Kuichling and Hawley[5] the per cent of gross

[3]See pages 365 to 411 of this Journal, 30, No. 3, September 1, 1916.
[4]This Journal, 30, No. 4, 453 to 478.
[5]Am. Water Works Jour., 1911.

revenue chargeable to fire protection according to population was estimated as follows:

Population	Per cent
5,000	77
10,000	60
50,000	32
100,000	23
300,000	13

It has been stated in the American Water Works Journal,[6] that the Wisconsin Public Utilities Commission has established for large cities $1.25 per capita for fire protection as a fair rate on the per capita basis. L. R. Howson[7] has stated, "In an ordinary city of 50,000 to 100,000 people, approximately 25 per cent to 35 per cent of the total income should be equitably received from the public for fire protection service. In February, 1904, Purdy[8] recommended that one-half the difference in money value per year of the premium where sprinkler service is used and where it is not used, less interest on the cost of the installation of the sprinkler system should be charged for the service. Hydrants and standpipes should be charged for at the prevailing rate to the town or city.

The revenue from fire protection may be obtained by a rate per hydrant of say $10.00 to $12.00 per year and the balance from an inch-diameter-foot charge on the total number of inch-feet of 4-in. and larger pipe. After deducting the revenue from miscellaneous service and from fire protection from the gross revenue required, the balance of the revenue should be derived from general water rates. These may be made to produce the required revenue by a study of the amount of water now used by each meter and the application of rates that will bring in the required revenue. In most cases, fixed or capacity charges are made according to sizes of meter, and all water used is charged for in addition, unless rates are based on a minimum charge which includes a certain amount of water.

Meter rates may consist of a minimum charge according to the capacity of the meter including a fixed quantity of water, with graduated charges for quantities used in excess of the minimum; or they may be based on a fixed service charge, sometimes called capacity charge, according to size of meter plus charge for water used, or wasted. The service charge is designed to cover the customer and fixed costs that are constant whether water is used or not, consisting of a charge on the cost of the meter, depreciation, taxes, reading, billing, testing and unregistered water, etc. It is thought by some that a

[6]Am. Water Works Jour., **25**, 75.
[7]Am. Water Works Jour., **23**, No. 7.
[8]Am. Water Works Jour., **18**, No. 2, 196.

minimum charge with an allowance of a certain amount of free water is more acceptable to the customer as it is difficult for the customer to understand the service charge no matter how carefully it may be explained.

Lower rates to large users are justified by the fact that it costs less to serve them than it does the small user, as the expense of serving one meter using say 500,000 g.p.d. is not to be compared with the expense of serving a thousand customers using 500 g.p.d. In some cases, it is a matter of competitive costs which makes the rate for large users low; that is, a large industrial user may be in a position to drive wells or take water from a nearby stream and pump the same at a low cost, and it is a question for the water works administration to decide whether to make a low rate and get the business or make a high rate and lose it. My opinion is that in such cases, water should not be sold below cost except up to the time that the water works can sell its output above cost; that is, large users are profitable at low rates until their demand exceeds the supply and requires capital expenditures which the revenue from the large users will not justify.

In July, 1934, The Public Utilities Commission of Connecticut ordered the following schedule of rates for The Ansonia Water Company:

METERED SERVICE

Quarterly Charges for Yearly Consumers

Water

Volume of water per cu. ft.

	per meter per quarter	Cost per 100 cu. ft.
First	2,000	$.20
Next	23,000	.15
Next	75,000	.13
Next	150,000	.12
Next	750,000	.11
All over	1,000,000	.06

Meters

Fixed Services Charges (these charges do not provide any water, but include setting and disconnecting the meter).

Size of Meter Inches	Charge	Size of Meter Inches	Charge
½ or ⅝	$ 1.50	3	$ 43.50
¾	2.25	4	63.00
1	5.40	6	118.50
1½	13.50	8	190.50
2	18.00	10	216.00

UNMETERED SERVICE

Annual Charges

Public Fire Service

Hydrant Charge.	For hydrants, company owned, per hydrant	$10.00
Inch-Foot Charge:	In addition to hydrant charge, on all mains 6 in. in diameter and larger, and all 4 in. mains installed prior to Jan. 1, 1923, per inch-foot	0.0092

Special Charges

For construction purposes and other temporary special services, the Company may establish special charges.

In January, 1937, after considerable negotiation with our largest customer, we were obliged to change our rates on all over 2,000,000 cu. ft. from 6c to 4c for the next 2,000,000 cu. ft. and on all over 4,000,000 cu. ft. from 6c to 2c per 100 cu. ft., to meet competition as this customer was in a position to develop his own supply to a considerable extent from wells.

Hazen in his book "Meter Rates for Water Works" makes these statements with respect to the service charge:

It is a device for separating some of the expense of maintaining individual services which have nothing to do with the delivery of water, and of keeping them separate and of charging them to each customer as a separate item in his bill. The service charge is an alternative for the minimum rate . . . it represents a more logical and more just arrangement. . . . The amount collected by the department from service charges may be expected to be greater than the amount resulting from excess collection in minimum rates, consequently the amount to be raised by meter rates will be reduced by a substantial amount. . . . Some popular opposition to the service charge grows out of the erroneous idea that the service charge is an additional charge and amounts to higher rates. As a matter of fact, it is simply a different way of distributing the burden and of changing it to correspond more nearly with the costs.

Hazen illustrated two systems by the following table:

	With a Minimum Rate of $8 per Annum and Water at 22c per 1000 gal.	With Service Charge of $5 per Annum and with Water at 15c per 1000 gal.
Customer taking no water	$8.00	$5.00
Customer taking 60 g.p.d., representing about the minimum full domestic consumption ..	8.00	8.27
Customer taking 100 g.p.d., being about the average domestic consumption	8.00	10.47
Customer taking 200 g.p.d., being above the average	16.00	15.95
Total charges for four takers	$40.00	$39.69

In all this discussion of rates, it should not be overlooked that water is cheaper than dirt, costing something like 7c per ton to the small consumer. The average annual cost for domestic use is probably about 1c per day per consumer, yet many persons are very water conscious and are niggardly in its use and critical of bills.

Col. Edwy L. Taylor, Chairman of the Connecticut Public Utilities Commission, stated in an address before this Association in May, 1936:

Considering the convenience of water piped into our houses, and that generally it is of the best possible quality, it is difficult to understand why there is ever any objection to rates charged for water service, for even the highest rates amount to little more than a few cents per day for the ordinary household. . . . Inadequate rates are certain to result in inadequate service and both rate payers and the utility suffer.

The present decrease in value of money, increasing the prices of commodities, labor and taxes, seems to indicate that present value rather than original cost should be taken as fair value in deciding rate cases. This would indicate that increases in rates cannot be avoided if expenses are to be covered and a fair return earned. In industrial centers where there have been large increases in rates of wages, it is difficult to keep public utility employees satisfied without raising wages. If wages are increased, rates must go up, and it seems only fair that they should go up as people are much better able to pay. Of course, it is true that public utility wages are steadier and amount to a regular income per week through bad times. Consideration should be given this.

Summary of Discussion

Mr. Roger Esty raised the question of reducing rates when retirements of bonds decreased the cost of supplying water. Mr. Harry U. Fuller pointed out the wisdom of being sure of the full extension of the water works plant before reductions are made, and Mr. Charles W. Sherman called attention to the Massachusetts law which prevents the setting aside of a reserve by municipal water departments and thus makes it difficult to design a proper rate structure. Mr. Fuller referred to the practice of giving the total charge for water service on the front of the water bill only and reporting the service charge and unit cost of water on the back of the bill. Mr. David E. Moulton stressed the fact that water departments sell service and that hence there should be a service charge.

DUAL SYSTEM OF WATER MAINS

BY DANIEL M. SULLIVAN*

[*Read September 24, 1937.*]

With the advent of the high-speed pleasure car and commercial vehicle has come the demand for a wider roadway and a better and smoother pavement for highways. This type of pavement is both expensive to lay and more costly to repair.

The riding public forgets that beneath the roadway there are laid water pipes and sewers, duct lines and gas pipes, all of which are just as necessary to the average person's comfort and the community's welfare as is the motor vehicle with its passengers or freight.

The street surface in the average community consists of granite blocks or one of the smooth types of pavement, usually with a concrete foundation which may or may not be reinforced. Once this type of roadway is broken into it is almost impossible to restore the street to its original condition.

When a street or highway is laid out and accepted by a municipality, it is assumed that such a thoroughfare may be used for whatever purposes streets ordinarily serve. This naturally includes in addition to the carrying of vehicles the laying and maintenance of underground water pipes and connections.

With the coming of automobiles and the speeding up of traffic, the street being used to its capacity by motor vehicles, any interruption of the free and easy movement of such vehicles is looked upon as a menace to the public. Consequently, an excavation in the street for repair of a main pipe or a service pipe is frowned upon by authorities and the department head responsible for opening the street surface has to do much explaining.

The problem of maintaining a water system under new and wide roadways is becoming so bothersome to the average citizen that water works officials are forced to remove pipes, etc., from roadways and to place them where they will not impede traffic in the event of repair operations.

The only available location left is the sidewalk. To place a main under one or the other sidewalk will not remove the objection, because services and hydrant connections will pass under the roadway to the opposite side of the street. In the event of repairs these will cause a slowing down of traffic, and the service pipes will of necessity

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be long. The other alternative is to lay two pipe lines, one on each side of the street, with short service and hydrant connections.

Whether it is possible to justify two pipe lines from an economical standpoint on streets 60 ft. or less in width might well be argued. But from a practical standpoint the water works official has no alternative if he is properly to maintain his mains and service pipes without impeding the general flow of vehicular traffic.

The dual system of water mains is not new. In fact, long before the laying of two water mains in a street was called a "dual system", the Boston water system was forced by circumstances to construct a main on each side of one of its boulevards. This was in 1896. Some 20 years ago Boston adopted the policy of laying a dual system, or two-main system, of underground water piping on all streets the width of which exceeded 80 ft.

With the dual system of water mains, no excavation need be made in the roadway, thus eliminating the excessive cost of repairing street openings. The streets will last longer if not disturbed by such openings, and the possibility of damage suits for injury to vehicles or persons passing over such openings is avoided. Traffic tie-ups are eliminated. Detouring of traffic is done away with, and the riding public is discommoded as little as possible.

When mains are installed in the sidewalk, the service-pipe connections are short. This naturally maintains a better pressure to the customer; stoppages are more easily freed, leaking service pipes are more readily located; and one shut-off on the service pipe is eliminated. The two-main system is less expensive to maintain, due to the fact that it is easier to excavate the sidewalk and keep it in repair. Excavations in sidewalks are not subjected to the pounding of heavy vehicles passing over them, and it is not necessary to wait a considerable length of time before the sidewalks are restored to their original condition.

Pipe lines in roadways are subjected to stresses and strains due to heavily loaded vehicles that pass over them. Pipes in the sidewalk areas are not subjected to the tremendous impacts that are created by these trucks. In a street carrying car tracks, the impact from street cars is eliminated, and the weakening of the main is prevented. Electrolysis from car lines is also eliminated or reduced.

All of the new traffic arteries constructed around the city of Boston incorporate the Dual System of water mains. The pipes are laid in the sidewalks, and where street widenings have occurred, the older main is allowed to remain in the street, and an additional main is laid along one of the sidewalks. All services on that side of the street are connected to the new main, the idea being that at a later date, when

conditions warrant, the main in the street will be abandoned and a new main laid in the sidewalk.

Due to the policy of laying dual mains in the chief arteries of the city, it is surprising how little maintenance work is necessary. The dual system recommends itself for its economy of maintenance and elimination of traffic interruptions.

Summary of Discussion

Mr. Sullivan, questioned by Mr. J. W. Randlette stated that the one shut-off saved in dual mains was the curb cock, the corporation cock taking its place. Mr. David A. Heffernan spoke of the difficulty in allocating space to all required services under the sidewalk. Mr. Sullivan described the practice followed in Boston, Mr. Leland G. Carlton, the system developed in Springfield, and Mr. William W. Brush the method adopted in New York.

HYDRANT CONNECTIONS AND THE CONTROL OF DUAL MAINS

BY ARTHUR F. BALLOU*

[*Read September 23, 1937.*]

Mains, valves, services and hydrants are the four essential components of the water distribution systems of our cities. Most of us will agree that water distribution systems are sufficiently vital to a community to command allocation of space in streets for their installation and use of the best materials and labor to assure their permanency. Beyond such agreement, opinions may differ. Climatic conditions, water quality, quantities of water required and various other factors must be considered. A wide variation in details has resulted and there is no definite standard of distribution systems.

In common practice the general arrangement of distribution systems comprises a main in each street, cross-connected with other mains for mutual delivery strength, and supplying water to services and hydrants along its route. This general plan has been handed down from generation to generation. Its continuing existence is now threatened. The pavements with which our streets are surfaced increase the cost of ditching. To reduce these costs some cities have already departed from the traditional practice of a single main under the pavement and have installed two mains in a street: one for purposes of general distribution located under one sidewalk; the other, which is frequently of smaller diameter, under the opposite walk to care for the demands of services for consumers located on that side of the street.

In some cities both these lines are installed as mains. This method doubles the mileage of pipe, and, as each main is connected with all others that it passes along its route, the number of valves is more than doubled, and some complications of control are added that would be better in avoidance than in accumulation. In other cities the second line is treated as a service header that extends under the sidewalks half way around a block and that connects at each end with a street main without extending under the street pavement.

As the installation of dual lines cuts in half the number of services that would be affected by a single break in a main, this service-header plan provides possibilities for a substantial reduction in the number of main-line valves without impairing reliabilty of service.

This paper does not deal with comparative costs. Those are for

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local determination. It is presented to call attention to a simple plan for providing reliability of service. While there is no apparent standard system of distribution, we may select for discussion, from the great variety of systems that this country possesses, one that meets many requirements and is sufficiently prevalent to be considered traditional. Let us construct a mental plan of this system.

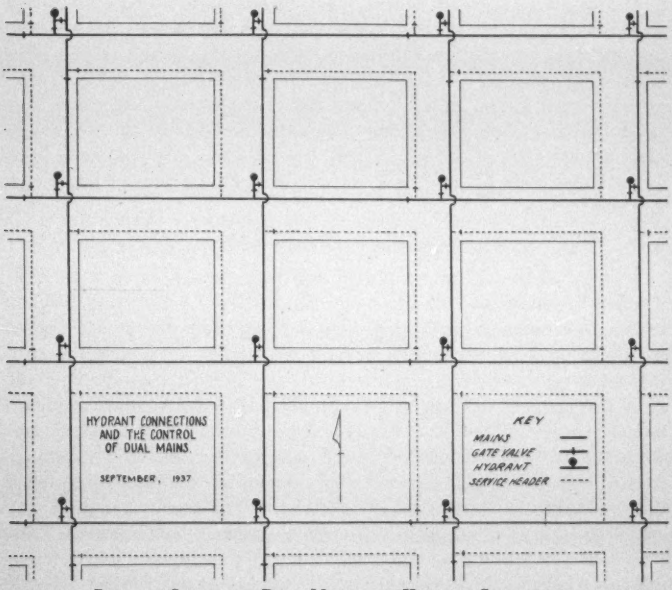
Our city is supplied at the center of its western border. The city blocks are rectangular, 400 ft. long east and west and 250 ft. deep north and south. Streets are 60 ft. wide. Lot frontages are 50 ft. At a typical intersection of an 8-in. main and a 6-in. lateral through a 4-way fitting, there is an 8-in. valve on the east, a 6-in. valve on the south and a 6-in. valve on the north. Beyond this north valve is a 6-in. tee for a fire hydrant which, with valve in the branch, is installed near the northeast corner. Services connect with the mains as required along the block fronts. The sizes of the mains mentioned are the smallest that occur in the system. Arteries and secondary feeders must be provided for adequate distribution. Actually at other intersections some of the north and south mains are larger than 6 ins. in diameter and many of the east and west lines are more than 8 ins. in diameter.. The general arrangement however is typical, and normally has given satisfactory service.

Since breaks may occur, let us consider the effect of shutting a main out of service. A broken hydrant requires no lengthy shut-down of a main, as a valve is installed in the hydrant branch. A break in a north and south main is a two-valve shut-down and takes out of service one hydrant and the smaller number of services, possibly a maximum of 10. A break in the east and west main is a 4-valve shut-down. It takes out of service the greater number of services, possibly a maximum of 16, and temporarily dead-ends the supply to one hydrant and to the intersection where all three of the main-line valves must be closed.

What can be done to simplify our intersection plan? Can we give more reliable service? This question has been partially answered in connection with large mains. There has been a very general feeling that the connection to an artery by means of a cross with a valve on each side will unduly delay the isolation of a broken section of the artery because of the need of closing two valves at each intersection. In many cases these intersecting mains may be 12, 16, or 20 in. in diameter. With a tee connection, only one valve need be operated, and because of the short length of this bypass connection, it is seldom that the valve would need to be of full size.

Let us use this tee connection in our general gridiron and construct another plan with pipes beneath the sidewalks. Let us consider

that the 6-in. main passes beneath the 8-in. main and that we have a valve in each line. To connect the mains, we use two tees and a short run of pipe. The connecting line is valved at its connection with each of the mains, and the tee for the hydrant takes off between these valves. We shall have made little if any change in strength of distribution; instead of a cross we shall have two tees and a short run of pipe; we shall have the same number of valves, four in number, with the two valves on the connecting pipe permanently allocated to the smaller pipes in the system.



PROPOSED SYSTEM OF DUAL MAINS AND HYDRANT CONNECTIONS.

What will be the effect of a break? To control a broken hydrant two valves must be closed instead of the traditional one. A break in a main will affect the services along the block front as before. For its control, two main valves will be closed and one on the connection supplying the hydrant, but the hydrant will remain in service with supply from the other main, and no temporary dead ends will be created as in the traditional plan by closing three valves at the same street intersection. Under the emergency condition of a single break, we shall have improved the reliability of hydrant service and the adequacy of local distribution.

Let us place upon our plan the service header under the opposite sidewalks. This may add a valve to be shut for control of a main break, but it makes a marked change in our service requirements. The maximum number of services affected by a single break in a main line is cut in half and, without increase in the maximum of the traditional plan, we can install a main valve in east and west streets at alternate intersections, or at a distance between valves of 920 ft., and on the north and south streets at intervals of 3 blocks, or at a distance of 930 ft.

The plan proposed adapts itself to standard fittings where the sidewalks are 7 ft. in width. The valve boxes will be near the hydrant, and the relative positions will indicate the function of the valves. The costs of installation are for local determination but, as the plan proposed permits a reduction in the number of valves required, which may be as much as 25%, and as the valves eliminated from the traditional plan include some of the larger sizes, the plan may also commend itself as reducing costs of materials and the annual charges for inspection and maintenance.

Summary of Discussion

In the discussion that followed this paper, Messrs. Percy A. Shaw, Charles W. Sherman, Daniel L. Sullivan, Arthur C. King and William W. Brush commented favorably upon the plan presented by Mr. Ballou for the control of dual mains where construction or reconstruction of the distribution system permitted the use of dual mains and made their employment desirable. Mr. Stephen H. Taylor called attention to the nearness of hydrant shut-offs to the hydrant which makes their closure difficult or impossible where old-type hydrants are employed, Messrs. Donald C. Calderwood and Charles W. Sherman questioned the possibility of employing dual mains in the non-rectangular city plans and varying topography of New England communities. Mr. David Heffernan objected to the mutual interference of different utilities which would be accentuated by crowding them under the side walks. Lack of understanding of the needs of utilities by town planners was voiced.

PAINTING FIRE HYDRANTS TO INDICATE CAPACITY

BY J. W. RANDLETTE.*

[*Read September 24, 1937.*]

Before discussing the merits of hydrant marking, it may be well to review briefly some of the steps that led to developing a plan for hydrant marking. In 1928, at one of the meetings of the Maine Water Utilities Association, the proposition was placed before that Association. After discussion a committee was appointed to look further into the matter and report at some future meeting, drafting a plan in concrete form for consideration by the Association. This committee worked diligently, and in 1929, placed before the Association a plan which was adopted and recommended to the Maine water utilities. Quite a few of the Maine water districts and companies at once put the plan into effect, and it met with so much commendation from both water companies and fire departments that is became apparent that if the plan was good for Maine it was good also for other locations. Some of the members of the committee took upon themselves the task of promoting through other interested organizations a national hydrant-marking plan.

The plan was proposed to the New England Water Works Association; the American Water Works Association; the New England Fire Chiefs Association; the International Fire Chiefs Association; and the insurance interests. In May 1934, a committee of the New England Water Works Association made a favorable report which was adopted, through the efforts of the members of the Maine Water Utilities Association. In June of that year, the New England Fire Chiefs Association, after lengthy discussion, ordered its committee to continue and to call a meeting in Boston of the associated interests for a conference. On August 2, 1934, a meeting was called at which representatives of water, fire and insurance interests were present. The following resolutions were drawn up:

That the idea of indicating relative available fire-service draft of hydrants by different colors is of substantial and growing interest of water and fire departments and worthy of the most careful consideration by all the organizations represented.

That these organizations be requested to take such steps as are necessary to bring the subject matter of the conference to their memberships for action thereon. As a basis for consideration by the various organizations represented it was also concluded to recommend:

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(a) That hydrants be classified as follows:
Class A — Flow capacity of 1,000 g.p.m. or greater
Class B — Flow capacity of 500 to 1,000 g.p.m.
Class C — Flow capacity of less than 500 g.p.m.

All capacities to be rated at 20 lbs. per sq. in. residual pressure by Pitometer tests of individual hydrants.

(b) That the following capacity-indicating color scheme be adopted as providing maximum visibility, simplicity and consistency with the colors used in signal work for safety, danger and the intermediate conditions:

All barrels to be *Chrome Yellow*

Class A—Tops and nozzle-caps *green*
Class B—Tops and nozzle-caps *orange*
Class C—Tops and nozzle-caps *red*

(c) That all location markers for flush hydrants should carry the same color background as above stated for Class indication, with such data as to dimensions stenciled or painted thereon as may be deemed necessary.

(d) That the colors shall be understood to signify only the individual capacity of the hydrant as tested and not group hydrant effect.

This resolution was practically the same as that adopted by the Maine Water Utilities Association except that the residual pressure was 10 lbs. higher. In the New England Water Works Association, the Committee on Public Water Supplies for Private Fire Protection emphasized, in addition to hydrant markings, that fire-department pumpers should be kept away from private fire hydrants to which sprinkler systems were connected.

Following the conference, the New England Fire Chiefs Association at its convention at New Bedford, in June 1935, adopted the hydrant-marking plan. The American Water Works Association and the International Fire Chiefs Association have had the matter placed before them but have never taken action.

Advantages of the Plan. Before recommending the plan to the Maine Association, the committee gave consideration to the advantages and disadvantages of the plan. The principal direct advantage of this plan is that it will enable fire departments to connect to the best hydrants available and to select those hydrants at a glance without delay; and that since the plan calls for flow tests of individual hydrants before they can be given their proper color, the water departments will have a valuable record of their entire systems. Uniform markings enable fire

departments, when responding to calls for assistance from neighboring towns and cities, to hook up to the best hydrants without the delay of getting in touch with local officials. Water works engineers are able to locate the weak spots in their systems. It gives the chief engineer of the fire department and the water works engineer uniform records and promotes coöperation between the two departments. The uniform residual pressure of 20 lbs. provides for a uniform test no matter in what town the system is located.

It will be noted that the color scheme conforms to the colors used almost universally in highway traffic signals, and that the driver of the fire truck or the water works employee is not confused by complicated markings. The barrel marking of chrome yellow gives the greatest visibility and at the same time blends with the natural surroundings whether it be a residential or business section. When the driver of a fire truck sees a hydrant with green top and nozzles he knows at a glance that that hydrant will give him the largest flow. Like the highway signal it indicates a clear way. When he sees a red-top hydrant he knows at once that like the highway signal it means danger. He will, therefore, locate a better hydrant if there is one in that vicinity, because the red top indicates the lowest flow. Of course the orange top indicates intermediate capacity.

While Maine was the pioneer in the marking plan, many cities in many states have adopted the plan. One of the best reports that we have had has come from Newark, N. J., where the chief of the fire department induced the water works engineer to try out the plan and put it into use. Only the highest commendation from both the chief and the water works engineer has been the result. The claim is made that the plan is as important to the fire department as the standardization of hose threads for hydrants and hose.

I do not know of a single disadvantage to the plan. Some opposition has been voiced by water works engineers and politicians. The objection of water works engineers is that on revaluation or valuation of a water system, predominance of red-top hydrants would be detrimental to reaching a fair value. Here again to my mind the plan shows its importance, for a uniformly tested and marked system becomes a yard stick for both the purchaser and the seller. It should not be condemned because it shows the apparent worth of the system. The tests show to the engineer whether the capacity of mains has been reduced by tuberculation. Political opposition is based on the fact that in many cities the water department is a big political factor. It is the plum of the party in power, or the reverse, and the claim is that uniform marking would forge a powerful weapon either for or against the party in power. I am not politically educated well enough to

discuss this opposition, except to say that it is to my mind a very weak argument against a plan that is so vital and important in the protection of life and property of the inhabitants of American cities. There is also an argument that the marking of hydrants, particularly where private companies control the water supply and distribution, will make a demand on the company for better mains in the sections where red-top hydrants appear. I have followed this up in a number of instances and have failed to find a single instance where there has been a demand from the public for their abatement where this plan has been adopted. In one of our Maine cities, in which the superintendant started to mark hydrants according to this plan, the local newspaper became interested, because the editor noticed a new color on the hydrant near his residence. When told that the color indicated to the fire department the amount of water that could be expected from that hydrant, he thought it was a wonderful thing. Since he never before knew that the color of a hydrant meant anything, he wrote two or three columns in his paper on the system stressing the importance of the system and what it meant to property owners. No thought was given to the fact that one hydrant showed a larger capacity than another, which is naturally to be expected due to the natural contour of the location.

After long and interesting study of the subject matter and with correspondence that would fill a brief case, my answer to the question raised in this paper is that fire hydrants should be painted to indicate capacity, and that the plan adopted by the water works and fire associations of New England has proved itself of value to those communities which have adopted it.

Summary of Discussion

Answering a question by Mr. Harold L. Brigham, Messrs. Randlette and Donald C. Calderwood were of the opinion that the insurance exchanges would not base their rating of distribution systems upon the marking given hydrants but upon the results of their own fire-flow tests.

Mr. Ernest A. Merrithew asked whether a special system of marking had been devised for the last hydrant on a dead-end main and received the answer that this practice had been discussed and that it was practicable to provide a suitable marking for this hydrant situation as well as for the size of main feeding hydrants.

Mr. William W. Brush reported that the system of marking hydrants had been adopted by the American Water Works Association.

Questioned about the marking of hydrants on separate distribution

systems provided for fire fighting, Mr. Randlette remarked that there was no reason for devising additional markings. Mr. Brigham reported that at Marlborough, Mass., the barrels of such hydrants were painted red while the barrels of hydrants converted to the domestic supply system were painted black.

PAYMENT BY THE STATE FOR RELOCATION OF WATER MAINS NECESSITATED BY STATE HIGHWAY PROJECTS

ERNEST A. MERRITHEW*

[*Read September 24, 1937.*]

The town of Saugus covers an area of about eleven and one-half square miles and has a population of 16,000. It has approximately 125 miles of roads and over 44 miles of water mains. It is purely a residential town.

In April 1936, after the close of the annual town meeting, we were approached by the State Department of Public Works regarding the relocation of water mains along the proposed new highway. This new road was to be constructed according to the Hayden-Cartwright Act under which the Federal Government furnishes one-half the cost and the state the remaining half. This project included nearly four miles of the Newburyport Turnpike, U. S. Route 1, which passes through Saugus. The work was to consist of building a modern road of two 44-ft. strips. Thirty-four feet of each strip was to be of Warrenite Bitulithic pavement and the remaining ten feet of Penolithic. A grass plot ranging in width from 6 to 20 ft. separated the two.

Along the old road in Saugus we had some 5450 ft. of 6-, 8-, and 10-in. main, 39 services and 18 hydrants to be lowered or relocated. Much of the work would be through solid ledge. Also in many instances, where cuts were to be made, our mains would be left practically on top of the ground. The necessary changes outlined by the State would mean the expenditure of about $20,000. This is a sum larger than the usual water maintenance appropriation for twelve months in the town of Saugus.

With the annual town meeting over, and without sufficient funds in our regular appropriations, it was necessary that we search elsewhere for funds to accomplish the required work. I visited the State Highway Office and talked the matter over with the senior engineer in charge of design. It was explained to him that the financial condition of the town was such that it would be impossible for us to stand this added expense. The matter was then taken up with a representative of the Federal Government, for all items of the work must have the approval of the Federal Inspector.

After several such conferences, it was agreed that the changes would be added to and paid for under the general contract. The contract was awarded, and work was begun in October 1936. No changes

*Superintendent of Public Works, Saugus, Mass.

or relocations of water mains were made however until December. Since that time the following work and installations have been accomplished:

18 hydrants
23 6-in. gates and boxes
3341 ft. of 6-in. cast-iron pipe
1390 ft. of 8-in. cast-iron pipe
600 ft. of 10-in. cast-iron pipe
3593 cu. yd. of trench excavated
383 cu. yd. of trench excavated

This work represents a total cost of $20,000. With the exception of one job where 125 ft. of 8-in. main were lowered, new stock was used. On all hydrant relocations, 6-in. valves and boxes were installed. All old lines were abandoned. Leadite compound was used for joints, and each joint was carefully bonded. All old-type hydrants were replaced with new Eddy hydrants at the expense of the town. In peat bogs where soil was removed from or near the mains, all joints were inspected again for leaks after the new gravel fill had had a chance to settle. At intervals of 1500 ft. lateral mains were laid under the new road for the purpose of caring for future developments.

In January 1937, a committee was appointed for the purpose of looking into the advisability of laying additional water mains along the new roadway. The committee consisted of one member of the Planning Board, one member of the Finance Committee, one member of the Fire Engineers, the Chief of the Fire Department, and the Superintendent of Public Works. This committee submitted plans for laying mains in sections that were without water and recommended that the size of the mains under the new road at principal intersections be increased. In some cases dual lines were planned for. Under this plan suitable fire protection was provided for all present and future properties.

The plan called for a bond issue of $40,000 which was approved and passed unanimously by the regular town meeting of 1937. After receiving the approval of the Emergency Finance Board the bonds were disposed of and work was begun at once. Under this bond issue a total of 12,462 ft. of 6-, 8-, 10- and 12-in. pipe with all necessary fittings and hydrants have been laid by the department.

In closing I desire to express my appreciation to the representatives of the various state and federal departments with whom I have had contact for their very willing coöperation. It has been a pleasure to do business with them, and it pleased me to learn of their apparent interest in the affairs of my town. In my opinion I feel that no concessions were made either by the state and federal departments or by the town which were not well deserved. I am certain, however,

that in all like instances, other cities and towns will receive the same gracious consideration and assistance that the town of Saugus has received.

Summary of Discussion

Messrs. Frank Gifford and W. C. Hawley brought out the difficulties faced by private water companies in connection with relocations of highways. In their cases the cost of changes had to be met by the company.

STEEL PIPE FOR WATER MAINS

BY E. H. THWAITS*

[*Read December 16, 1937.*]

Steel pipe for water mains is an old subject. Pipe has been made of steel and steel pipe has been used for water transportation since the inception of steel making. Steel pipe has been made in Pennslyvania and several other states since 1750. The improvement in the fabrication of steel pipe made of steel plates advanced with the perfecting of rolling-mill equipment during the years 1840 to 1850.

SERVICE RECORD

Tabulations of service records of steel pipe in use in the United States are available and interesting.

F. C. Scobey, Senior Irrigation Engineer, Bureau of Public Roads, U. S. Department of Agriculture, in Technical Bulletin No. 150, "The Flow of Water in Riveted Steel and Analogous Pipes," shows a 40-page record of steel pipe installation, beginning with two installations, dating back to 1851, of 8-in. and 12-in. pipe made of steel plates covered with hot bitumen, up to and including modern steel pipe laid in recent years.

The recent Approval Report of the Underwriters' Laboratories, Inc., of the National Board of Fire Underwriters, on "Steel Pipe Line for Underground Water Service" shows a detailed list of approximately 1000 steel pipe installations in 274 locations in the United States and Canada, totaling 16,200,000 ft., made by the Lock-bar, riveted, seamless, lapweld, electric weld, spiral weld, and hammer-weld methods. This splendid record shows the location and date of each installation, the length, size, and type of steel pipe, and the types of protective coating, if any. The record shows installations dating back to 1871, in Pittsburgh, Pa.; to 1877, in Detroit, Mich.; to 1889, in Vancouver, B. C.; to 1890 in Buffalo, N. Y.; to 1891 in Newark, N. J.; to 1893 in Rochester, and Syracuse, N. Y.; to 1894 in Portland, Ore., and Little Falls, N. J.; to 1895 in Boonton, and Kearny, N. J.; to 1896 in Newark, N. J., Cleveland, O., New Bedford, Mass., Rochester, N. Y., Minneapolis, Minn., and Bayonne, N. J.; and to 1897 in Paterson, N. J. All of these installations are now 40 to 66 years old, and in spite of the fact that they were laid before the advent of protective coatings and linings, they are reported to be rendering splendid service.

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Of particular interest to New England, this record further shows the following installations: Quincy, Mass., 1887; New Bedford, Mass., 1896; Springfield, Mass., 16 installations, totaling 227,759 ft. of steel pipe, laid from 1905 to 1927, 190,917 ft. of which were laid in 1905, 1906 and 1907,—now 30 years old. Some of these lines received protective coatings or linings of a special type of coal tar, according to specification by Allen Hazen, and are reported to be in excellent condition. Further installations are Rutland, Vt., 1913; Brandon, Vt., 1916; Port Henry, Vt., 1919; Boston, Mass., 30 installations, totaling 248,889 ft., all laid since 1924; Providence, R. I., 1924; Cambridge, Mass., 1931; Portland, Me., 1931; Winthrop, Holliston, Medford and Everett, Mass., 1937. A considerable amount of steel pipe has been laid in other New England cities since 1930.

New York City has 60 installations totaling 410,660 ft. of steel pipe laid from 1910 to 1933. An additional list of smaller sized steel pipe installations is available, ranging from 4 in. to 20 in., totaling approximately 17,000,000 ft. in over 200 cities and towns, in the United States and Canada, showing the same types of fabrication of pipe listed in the Underwriters' Report. These two recorded lists, totaling more than 33,000,000 ft. of steel pipe installations, obviously are incomplete. There is probably no way of knowing what is the actual total footage of steel pipe for water mains, in service at the present time, but it is known to be far in excess of the total figures shown.

Since cold water pressure mains almost never fail by corrosion from the inside but only from the outside, due to the action of corrosive soils, records of all types of steel pipe installations, whether they carry water or other fluids, are of interest and importance in a general study of their life expectancy under all kinds of soil conditions. No type of pipe is more widely distributed and used under all types of practical conditions than is steel pipe. Of interest is the following report by the Oil and Gas Journal of Tulsa, Oklahoma, for October, 1936, relative to gas lines:

Available information indicates that the gathering and trunk line systems covering oil and gasoline transportation, total approximately 115,000 miles. About half of this total mileage is represented by trunk line systems, practically all of which are shown on our map. The natural gas pipe line mileage, not including the distribution systems within the towns and cities totals approximately 70,000 miles.

The American Gas Journal reports in 1937, as follows:

Figures alone cannot tell the story of the gas industry, which, with a capital investment of approximately $5,000,000,000 serves through its 266,400 miles of gas mains, more than 80,000,000 people.

Most of this pipe is steel, with the exception of some of the distribution systems. The larger part of this tremendous mileage of steel pipe was laid before protective coatings and proper methods of application were perfected.

The Manufacturers' Edition of Engineering Construction in May, 1937, announced the following:

Major steel pipe line contracts reported by Engineering News Record in 1936, totaled 13,624,818 lineal feet, the highest volume since 1930, the total for which year being 30,919,377 lin. ft. The purposes for which these lines were built are—Oil, 6,946,570 lineal feet, Gas—6,157,860 lineal feet, Water Works—373,438 lineal feet, and others not classified—146,850 lineal feet.

These figures also are somewhat incomplete, as a study of the breakdown shows that approximately 500,000 lineal feet of the smaller sizes used in water distribution systems by this company are not recorded.

Rossiter S. Scott, Consulting Water Works Engineer, formerly associated with the late Nicholas Hill, of New York City, and now with the S. R. Dresser Manufacturing Company, in his illuminating paper on "The Good Record of ¼-in. Wall Steel Pipe in Water Transmission," offers the following common sense conclusions:

"It is a matter of record that ¼-in. steel water pipe laid 40 to 50 years ago in various parts of the country is in good condition today and giving useful service. It is recognized as a fact that the steel pipe of twenty-five years ago was inferior in quality to the steel plate produced and used for pipe in these modern times.

Corrosive soil, through research investigations, is found to be rare in this country and according to the Bureau of Standards' thorough investigations (see U. S. Bureau of Standards Bulletin No. 16), only about 5% to 10% of the soil in this county is seriously corrosive. The significance of these investigations is that they have broken down erroneous assumptions concerning the life of steel pipe and have thrown the searchlight on facts which refute objections against the use of steel pipe.

Today an efficient modern pipe coating is available to the designing engineer, while 40 to 50 years ago, or even 10 or 20 years ago, the engineer specifying ¼-in. steel pipe or thereabouts, did not have this high protective value, as given by modern coatings, for the steel water pipe that was installed.

The modern coal-tar-base enamel coatings have the qualifications for prolonging greatly the life of steel pipe installations. In New York City, a bitumastic hand-brushed coating placed in steel pipe over twenty years ago is in a splendid condition after two decades of serv-

ice and shows remarkable bond value in contact with the pipe. The brush-marks, when the pipe was examined several years ago, were as though the pipe had been newly coated. Mr. W. W. Brush, Former Chief Engineer of the N. Y. Department of Water Supply, Gas and Electricity, personally examined this coating at the end of that period of time.

If the rust action of steel pipe can be delayed from taking place by the application of bituminous coatings and the life of modern protective coatings conservatively estimated at 40 to 50 years then ¼-in. wall steel pipe, which already has served for this number of years in good condition and continuing to give useful service (without having had the advantage of a really good pipe coating), would naturally lead one reasonably to believe that with a modern bituminous coating a ¼-in. wall steel pipe line would last practically as long as any other material used for pipe line construction under similar corrosive condition."

The records, referred to, show steel pipe installations dating back to 1851 and 1871, covering periods of 86 and 66 years, respectively. These same records show a considerable amount of steel pipe laid 30, 40 and 50 years ago, that is still rendering good service, and will continue to do so for many years to come. Lanpher, late of the Pittsburgh Water Department, reports in the Journal of the American Water Works Association, for May, 1930:

"While we consider a life of fifty years for pipe made of soft steel plates, to be a fair average, it is evident that Pittsburgh will get a far greater life out of some of its steel mains."

Laboon, of the Chester Engineers, of Pittsburgh, under the same article says:

"We have seen steel pipe in the water works system of Pittsburgh taken up after thirty years of service, which pipe showed some tuberculation on the interior, but very little rusting on the exterior, for which an additional life of 30 to 40 years would not be too great."

Jensen, of the Minneapolis Water Department, also says in the same article:

"Two steel lines, each 3 miles in length, built in 1897, are now 32 years old, and are in excellent condition. From all observation, it now appears that these lines should be expected to continue in service for another similar period of time. Certainly the body of the metal is practically intact, the inside is slightly rough in spots, but the structural strength is unimpaired."

The foregoing facts are fortified by the conclusions of the Na-

tional Bureau of Standards Soil Corrosion Studies which were commenced in 1922, covering the effect of 47 different soils throughout the United States, on more than 30,000 samples of various types of pipe, that less than 10% of the soils of the United States are seriously corrosive. These facts, again fortified by the fact that modern protective coatings and linings and methods of application have been developed to a high degree, should demonstrate that a modern steel water main, if properly installed and protected conservatively, should attain a useful life of approximately 100 years.

Advantages of Modern Steel Pipe Water Mains

Steel pipe has many advantages due to its physical characteristics. Besides being strong, tough and flexible, it yields a high initial and sustained flow capacity, with consequent high pressures and low pumping costs. Steel pipe when assembled with modern mechanical couplings is "bottle tight," for which no "leakage factor" need be considered in the initial design or construction. Because of its physical strength and toughness, no "breakage factor" need be considered in the initial design, construction and maintenance. The factors contributing to the economic use of modern steel water mains are many. Because of its long average length, and relatively few joints per mile, because it is laid above the ground, avoiding the necessity of digging bellholes and dewatering trenches, considerable saving in labor is effected when laying steel pipe as compared to laying ordinary water mains.

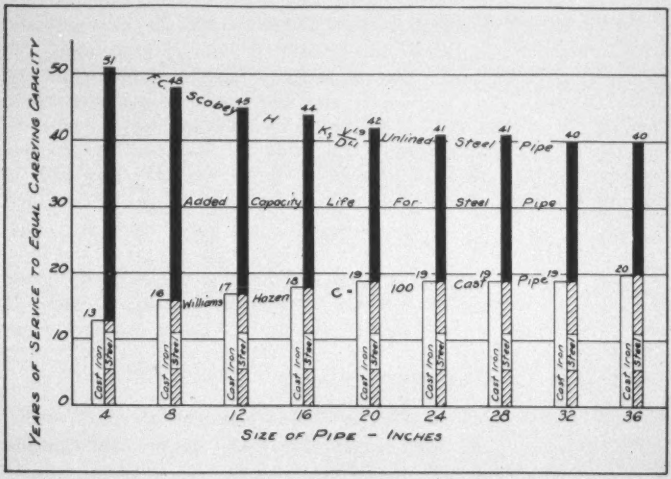
A tabulation of some of these details follows:

Characteristics of Steel Pipe. Great physical strength (60,000 to 80,000 lbs. per sq. inch) tensile. Extremely ductile, will elongate 18% in 8-in., which will more than take care of ordinary stresses and strains, will bend and deflect, has great strength as a continuous beam, will not shatter, most adaptable to street conditions and resists and prevents ordinary breaks caused by traffic vibrations, earth movements, shock from water hammer, blasting, earthquakes, etc.

Carrying Capacity. Unlined steel water mains with continuous interiors have average Hazen- Williams "C" Values of 140, or Scobey's K of 0.32. This is 7.5% greater in initial carrying capacity than ordinary water mains with a "C" value of 130, and an average carrying capacity 20% greater than the ordinary water main after an average of 18 years of service, when "C" has been reduced to 100 by corrosion and tuberculation.

A comparison of the capacity and flow data given by F. C. Scobey in Technical Bulletin 150 and the Hazen & Williams Flow Table data

shows the following interesting results of the years of service when carrying capacities become equal. An unlined steel water main 8-in. in diameter will have the same average carrying capacity after 48 years of service that an ordinary 8-in. water main will have at the end of 16 years of service. A 12-in. steel main will have the same average carrying capacity after 45 years of service that an ordinary 12-in. water main will have at the end of 17 years of service. A 16-in. steel main will have the same carrying capacity after 44 years of service that the ordinary water main will have at the end of only 18 years of service, etc. These data are presented in the accompanying graph.



Field tests made by the Pitometer Company show that steel water mains, lined with mechanically applied coal-tar-base enamel will have an average "C" value in excess of 150 after laying. This means that steel pipe so lined will have an average initial carrying capacity 15.3% greater than the ordinary water main with an average "C" value of 130.

Because a well designed coal-tar-base enamel is a fundamentally correct water main lining material, because it is properly bonded to the pipe wall, because it is water proof, and because it is insoluble in water-borne acids and alkalis, and domestic sewage, it prevents tuberculation, corrosion and incrustation and consequently maintains a high carrying capacity ("C" value of 150) throughout the life of the pipe. It will, therefore, have an average carrying capacity 50% greater,

after an average of 18 years of service than ordinary water pipe that has tuberculated and has had its carrying capacity reduced to a "C" value of 100 in that period. Such lined steel pipe can, therefore, be designed and purchased with proportionately smaller diameters.

Leakage Factor. The use of steel pipe, in long lengths with mechanical type couplings, reduces the number of joints per mile from an average of 440 and 330 for 12-ft. and 16-ft. lengths of ordinary water pipe respectively, to 130 for average 40-ft. lengths of steel pipe. This large reduction in the number of joints not only eliminates many of the sources of trouble but makes steel water mains "bottle tight." The average leakage loss in the present distribution systems in the United States exceeds 15% of the total annual water consumption in each system. In the design of steel pipe water systems, no allowance need be made to compensate for leakage as is generally the practice with ordinary water mains using handmade joints.

Breakage Factor. Because of the great strength, ductility, and flexibility of steel water mains, they will not crack or burst under the stress of "street conditions" and will never shatter under any conditions. Breakage, with its costly loss of water and with consequent damage to mains, streets, paving, buildings, merchandise, and business, is practically eliminated by the use of steel pipe for water mains.

Economy. It requires an average of 10% more power to pump through and overcome friction losses in an ordinary water main when new, an average of 76% more power after 17 years of service, and an average of 155% more power after 35 years of service than to pump through and overcome friction losses in an average steel water main with a spun bituminous enamel lining. Laying and field costs of water mains have been reduced from 15% to 25% by the use of steel pipe because of lightness in hauling and handling, laying length (average 40 ft.), reduced number of joints and couplings per mile, narrow trench, no bell holes, and no need for dewatering of trench. All laying is done continuously above trench on supports, as work proceeds, and the pipe is lowered back of construction.

Adaptability. The equipment necessary to lay steel water mains is very simple and not costly. The laying and handling of steel water mains in construction is simple, rapid and economical. A wide choice in types of couplings, fittings, reducers, service connections, saddles and adapters is available to construct either a complete steel pipe water system or to change over from other types of pipe to steel.

Corrosion

Soil Corrosion. The National Bureau of Standards of the United States Department of Commerce in 1922 began a study of the action of soils on buried pipe. It buried many different sets in 47 soils throughout the United States. Each set comprised a number of the same samples of specimens of the more commonly used uncoated pipe materials. Samples of each set were removed at intervals of 2 years, but, because of the low corrosivity of some soils, a less frequent examination was sufficient in some locations. Each time samples were removed, they were replaced by specimens for further and special study until a total number of more than 30,000 was reached. By 1932, after 10 years, specimens were removed from only the more corrosive soils for study. From these progressive and final studies some important conclusions were reached.

The following quotations are from Research Papers 638 and 883, which appeared in the Journal of Research of the National Bureau of Standards, volumes 12 and 16, January 1934, and May 1936, respectively.

"Consideration of these data does not materially alter the conclusions reached earlier that the character of the soil controls the rates of corrosion of ferrous materials and that in the same soil all of the commonly used ferrous materials corrode at nearly the same rate.

The data presented in this report are for the more corrosive soils in the investigation and do not represent the average corrosiveness of all soils.

There are indications that the rate of corrosion decreases with time in most soils because of more stable trench conditions or the formation of corrosion products. The rate of decrease in general diminishes with time, indicating that a fixed rate of corrosion may ultimately be reached.

Under similar soil conditions the wrought-iron and steel specimens corroded at approximately the same rates during the first 12 years of exposure. In many of the soils under tests, especially those in the arid regions containing large amounts of soluble salts, the rate of corrosion of cast iron is somewhat greater than that of steel. From a practical standpoint the thickness of the material and the nature of the corrosion products should also be taken into account in determining the material most suitable for some soil condition.

The relation of the pit depth to the duration of the exposure depends on soil conditions. In some types of soil the penetration is nearly proportional to the time of exposure, but in other soils pit depths deepen very slowly after soil conditions have become stable and corrosion products have formed on the surface of the pipe. This fact has an important bearing on the estimation of pipe life. In general, the

life of a pipe should not be estimated solely from its age and the depth of the deepest pit because in most soil the rate of corrosion decreases with the time of exposure."

It is, therefore, apparent from the above conclusions that each pipe installation becomes a problem in itself. Inasmuch as all ferrous pipe materials corrode and at nearly the same rate under the same soil conditions, it becomes necessary and important to make proper and sufficient soil analyses to determine the nature of the protective coverings required in various soils even on the same pipe line, so that appropriate specifications can be written and the greatest economic saving affected.

Water Corrosion—Tuberculation. This is a combination of corrosion and incrustation and is caused by the growth and development of iron-consuming bacteria, according to H. G. Reddick and S. E. Linderman, U. S. Pipe and Foundry Company, as reported in Water Works and Sewerage, October 1931:

"Each one of these incrustations consists of a cone-like structure which grows by addition of concentric layers. The central portion is black and soft when fresh. This black substance often contains a small percentage of sulphid of iron and becomes red upon exposure to air. The middle layers are composed of ferric oxide. The outside layers are composed, for the most part, of ferric oxide interspersed with hard black layers of magnetic oxide. All of these tubercles seem to be nodular excrescenses grown by accretion and formed of concentric layers as is limonite."

Tubercles resembling barnacles are formed according to these workers by the corrosive action of bacterial development, probably accompanied by the precipitation of some of the mineral content of the water. These tubercles grow to several inches in diameter and several inches in thickness and cause great loss in carrying capacity as well as an increase in pumping and operating costs.

These data show that not all soils and waters are corrosive; that less than 10% of the soils in the United States are seriously corrosive; and that waters with a low alkaline content are only slightly corrosive and tuberculating.

In some soils and with some waters, unprotected steel pipe will last for more than fifty years as is evidenced by service records in many sections of the United States.

The application of modern pipe protection materials should therefore eliminate tuberculation entirely and decrease soil corrosion to a minimum.

Protective Coatings and Linings

We have come a long way and made vast improvements in the developments of pipe protection materials and methods of application and testing since the days of the old fashioned hot asphalt dipping practices. The economic solution of the "universal corrosion factor" is the dream of every pipe manufacturer. We have passed through some costly experimental stages: one pipe manufacturer has spent approximately $3,000,000 on a glass coating process for pipe lines, and another has spent a considerable amount developing a silica gas-impregnating process of corrosion protection. These have resulted in a fair approach to the solution sought, but not an economical one, as these processes cost approximately as much as the original pipe. Other experiments by manufacturers of protective materials, include coating pipe with celluloid, cellulose, vulcanized rubber, bakelite and other materials. They have proved also quite effective, but still too costly.

Modern coal-tar-base enamels give the most effective economical approach to the solution of the pipe corrosion problem. The present wide use of coal-tar-base enamels and the elimination of the bad practice of hot-dipped asphalt coating by some steel pipe manufacturers are doing much to increase the confidence of designing engineers and water works officials in the use of protected steel pipe for water mains.

Linden Stuart, President of the Wailes Dove-Hermiston Corporation, in his interesting article, "Reconditioning Water Supply Lines with Bituminous Enamel", in the Journal American Water Works, August, 1935, states: "Laboratory analyses of old asphalt-dipped coatings, from lines that have been in service from 8 to 23 years, show that these coatings have absorbed from 30 to 60% moisture," while, "Laboratory analyses—of coal tar coatings,—on the interior of several large diameter water lines, where the coating was subjected to water under pressure day and night for periods as long as 18 years, showed a moisture absorption of only 0.1 to 0.25%." These facts vividly demonstrate the difference in water absorption characteristics of coal tars and asphalts. In all fairness, however, it must be borne in mind that modern asphalt-base enamels with 20 to 25% inert silica base fillers are not to be confused with the ordinary unfilled asphalts used in the hot-dipping process. Such modern filled-asphalt enamels also can be made to have a very low water absorption characteristic and, when used on pipe lines in 90% of the non-corrosive soils throughout the United States, good protection is afforded at a very low cost.

Aside from a good basic corrosion protection material, the most important thing is to effect a good bond to the metallic surface, if protection is to be at all effective.

One of the reasons why steel pipe, especially when used for water mains has in some intances been given such a "black eye" in the past, is because of the continued practice of steel pipe manufacturers in using old-fashioned hot-dipped asphalt methods. It was not only the improper use of a material having a high water absorption characteristic, but also the method of application. Even though the pipe was properly cleaned and in some instances primed before hot dipping, the primers were redissolved at the dipping temperatures of 450° to 475° F. The hot bitumen coming in contact with the metallic pipe wall expanded the entrained air in the pipe surface thus causing blow-holes and pin-holes. The pipe thus emerged from the hot-dipping bath with a coating unbonded and porous. This poor mechanical condition of the pipe coating probably accounted for as much water absorption and rapid corrosion of the pipe wall as the improper material itself.

In the interests of good pipe protection practice, the writer's company dismantled a costly dipping plant and discontinued the practice of hot-dipping steel pipe lines in asphalt.

In fairness to the steel pipe industry, however, asphalts were not used merely because they were less expensive than coal tars. The reason for the long usage of asphalt as a pipe protection material lies in its physical characteristics. In other words, asphalts remained quite plastic and were not self-cracking at low temperatures and did not flow badly at relatively high working temperatures while coal tar pitches were brittle at normal temperatures. Coal tars are by-products of the steel industries' coke-making process, and have been, from time to time, drugs on the market and burned for fuel in the steel mills.

Within the last ten years, the process of plasticizing coal-tar pitches has been perfected, until now, modern coal tar pitches can be produced with such a wide temperature range as not to be self-cracking at temperatures of minus 40°F., nor will they flow or sag at temperatures as high as 175° to 200°F. One company now claims an upper limit of 250°F. Thus, we attain with a modern coal tar enamel, the physical characteristics of an asphalt, in regard to temperature range, and retain the desirable characteristics of a coal tar in regard to its water absorption characteristics. Very few data are available in regard to the plasticizing process involved. Briefly, we understand it to be accomplished by a combination of heat, pressure and centrifuging. A redistribution of the molecular structure is probably effected in a manner similar to the "Cracking Process" so well known and so universally used in petroleum industry.

The development of coal-tar-base enamels having this wide temperature range makes their use more practical under all outside

working conditions. Designing engineers and water works officials need no longer have fears concerning modern protective coatings cracking, flowing or sagging at any practical working temperatures during construction, as they have had in the past. In fact, coated and lined steel pipe now is being carried "in stock" by some pipe jobbers, and by some water works departments, so stable have these products become.

Some Economic Factors Affecting Water Transportation in Pipe Lines

The New England Water Works Association's Report on Pipe Line Coefficients and Effect of Age Thereon, is probably the most serious and practical study of the economics of water transportation in pipe lines. The astounding conclusions reached by the committee making this report are well known. A few of the high lights are, however, worth reviewing. The first conclusion, namely, that "The average actual loss in capacity of tar-coated cast-iron pipe after 30 years of service based on a total of 473 tests in 19 different systems, was 52%," is insufficient in itself. A review of the breakdown of these tests show that 132 were made in the Mississippi River Basin, 68 in the Great Lakes Region, 103 with eastern surface water supplies and 170 eastern surface, eastern well water, and miscellaneous supplies. The tabulation of these data shown on page 255 of this report is an interesting study in the correlation of pH values and loss in pipe carrying capacities. This tabulation shows that the 132 tests made in the Mississippi River Basin with an average pH value of 8.8 and that the actual loss in capacity after only 30 years of service with these relatively low tuberculating waters, was 31.8%. The 68 tests made in the Great Lakes Region show an average pH value of the water carried of 7.6 and an actual loss in capacity at the end of this same period of 37.8%. The 103 tests, made with eastern surface supplies show an average pH value of 7.0, which is the neutral point on the pH scale, and an actual loss in capacity at the end of the 30-year period of 46.4%. The 101 tests made with eastern surface supplies and Long Island well waters, had pH values of 6.7 and 6.2, respectively, and showed capacity losses at the end of this period of 66.4 and 72.8, respectively. The 69 miscellaneous supplies had an average pH value of 7.1 with a loss in capacity for this period of 58.4%. The average, then, of these 473 tests, is a pH value of 7.28 and an average loss in a capacity of 52.3% in 30 years.

It is of further interest to note that the average loss in capacity predicted for these waters by Hazen and Williams was only 34.4%.

This becomes important to designing engineers when using the Hazen and Williams Tables in their work. These tables are now shown to be very conservative and perhaps did not take into consideration, as did Scobey in Technical Bulletin No. 150, the difference between active eastern waters and relatively inactive waters in other parts of the United States.

The Committee's summary statement that, "The vast financial loss, resulting from the rapid capacity reduction of pipe systems—is a matter of major importance to the water works industry, and is believed of sufficient moment to warrant the determination in each system of the rate and cause of loss, as a basis for the adoption of the best preventive measures, whether they are provisions for permanent linings or corrective treatment for the water supply", is believed, has not been taken seriously enough by designing engineers and water works officials. Certainly there is no sound economic or practical reason why engineers should specify and water works officials should purchase pipe lines that grow progressively smaller in capacity as demands grow progressively greater.

A few quotations from a paper by Frank A. Barbour, Consulting Engineer, Boston, Mass., presented at the Los Angeles Convention of the American Water Works Association, in June, 1936, entitled "Economic Significance of Improved Linings" are in order at this time. He says in part:

"The tests reported by the Committee, therefore, show that instead of the 30% capacity loss which has been commonly assumed to result at some more or less indefinite future date, substantially greater losses, in the smaller sizes, running up to double 30% must be recognized.

In the light of these results the question may well be asked as to whether there is any economic justification for the continued use of tar-dipped pipe.

The investment value of a cast-iron pipe is measured by the hydraulic usefulness of the pipe, and not by its life as a metallic structure. In the average water works the cast-iron pipe lines probably account for more than 75% of the total cost of the physical plant, and at the present time, more than 85% of the tonnage of cast iron pipe sold for water works purposes is tar-dip coated. Is there any rational explanation of the continued acceptance of a coating which permits such rapid loss in value, of so large a part of the total investment in water works systems, as is indicated by the report of the Committee?"

So widely have the results of this splendid report been accepted by engineers throughout the United States, that many have predicted

that there soon will be no more unlined pipe used in the water works industry in this country and that present practices will be discontinued in less than five years.

Conclusion

In conclusion, we again wish to call to the attention of designing engineers and water works officials the fact that pipe lines should be designed and purchased on the basis of carrying capacity and low operating and maintenance costs; that useful life should receive prime consideration rather than just length of life; furthermore, that municipalities, purchasing modern steel pipe lines with protective coatings and linings and mechanical couplings, are purchasing an ideal material for the purpose for which it is to be used, namely, a material that has exceptionally high carrying capacity; is "bottle tight"; will not develop the high leakage losses encountered in ordinary pipe systems, due to joint leakage caused by vibration, shock, settling, and water hammer; will not break due to exceptional causes; will not shatter under any circumstances; and possesses low laying costs, due to the reduced number of joints per mile and the ability to lay above the trench and to use a narrow trench without bell holes and without the necessity of dewatering.

Discussion

Sidney S. Anthony*. I am interested in the tapping of steel pipe for services. How is this done?

Mr. Thwaits. Tapping always causes water works officials concern. We have for many years tapped light-wall steel pipe by the use of pipe saddles, screwing the corporation cock into the saddle itself. We have now developed two types of taps for light-wall steel pipe: One employs an expanding ring, and the other an expanding bushing principle. The expanding bushing, which we have ready for production and are actually using, is nothing more than a lead Babbit bushing put onto an ordinary corporation cock, one size larger than the corporation cock. The pipe is tapped with an ordinary tapping machine under pressure. In hundreds of taps made, the pipe lining has not shattered away any more than to form a slightly ragged edge. In tapping under pressure the corporation cock is inserted in exactly the same manner as in an ordinary cast-iron main.

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MEASUREMENT OF SAND EXPANSION

BY H. J. KRUM* AND EVERETT M. JONES†

[*Read September 23, 1937.*]

The purpose of this paper is to present a preliminary report of studies made on the use of a float in a model filter for indicating sand expansion in filter washing.

With the exception of filter washing, practically every step in the process of purification of water in a rapid sand filtration plant is controlled by meters and tests. In some plants, the operator is limited to a definite period of time and wash water rate; but as a rule he is relied upon to use his own judgment as to the manner of reaching maximum velocity, the length of time at this rate, and the rate of closing the valve at the end of the wash. This is particularly true in smaller plants.

Allentown has a 10-m.g.d. filtration plant, consisting of 8 filters, each filter having a capacity of 1.25-m.g.d. Our plant is not provided with a wash water rate indicator, therefore, we have no visual means of knowing the rate of application of wash water and must depend entirely upon the judgment of the operator. A study of the data on filter washing shows that one of the operators used an average of 4,600 gal., or 12% less wash water per filter, than the other four operators. One of the observant operators brought up the question as to who was washing the filters correctly. Obviously, the standardization of filter washing was the answer. Our first experiment, to establish a standard turbidity end point, was with a photo electric cell. This failed, for reasons which will not be discussed in this paper.

In a search of the literature for some procedure or apparatus that might aid in a more scientific method of filter washing, we found that Hulbert and Herring's "Studies on the Washing of Rapid Sand Filters"[1] described two methods for measuring sand expansion in filter washing. Briefly, the first is a submarine lamp, which is lowered into the expanded sand bed to measure the percentage of expansion. The second method is called a sand expansion indicator, which will be discussed in detail later. Inquiry revealed that this piece of apparatus was not on the market, and that the Simplex Valve & Meter Co. had the sole rights to its manufacture.

Our objective was a sand bed that did not have cracks; one that was practically free from mud balls and that did not pile up sand

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[1]Hulbert and Herring. Jour. A. W. W. A., **21**, No. 11 (1929).

in the corners of the bed, or pull away from the side walls. A bed containing clean sand does not have these objectionable features.

Baylis[2] considers filters in excellent condition when the volume of mud balls in any part of the bed is not greater than 0.1% of the volume of sand; when it is greater than 0.2%, remedial measures should be applied. Hulbert and Herring[1] state that "If a filter is composed of very clean sand (2% of coating or less) all mud mounds are absent, no shrinking whatever takes place." Hopkins[3] states that the clarity of the final wash water is a usual criterion of cleanliness of the filter bed.

Methods of Washing Filters. The first rapid sand filters were back washed, after a short period of agitation with air, with a comparatively low velocity of wash. In 1929, Hulbert and Herring introduced the high-velocity wash, and shortly after Baylis advocated surface wash followed by moderate-velocity wash.

Wash Water Details. Armstrong states "It can readily be seen that any change in the depth and grading of sand, temperature, or in the rate of applied wash water would affect the level of the top of the sand bed during the washing period." Allen Hazen presented a formula for calculating sand expansion from the sand size, temperature of wash water and sand depth. Hulbert and Herring also used these factors for the same purpose. They found that at 50% sand expansion, by the application of a relatively high-velocity wash, the filter sand could be kept clean and long filter runs could be obtained, also, that "We are not prepared to claim universal applicability for the expansion index, however, it may very well be that sands of different characteristics require different degrees of expansion for satisfactory cleaning." W. C. Lawrence[4] of Cleveland obtained similar results with 50% sand expansion reporting a 69% increase in hourly period of service for each filter. The total amount of wash water saved over a three year period was 771.5 m. g. representing, at a cost of $40 per million gallons, a total saving of $30,860. J. Clark Keith[5] is of the opinion that it is important that sand expansion be accurately determined at regular intervals. George F. Gilkinson,[6] of Kansas City, Mo., shows that with a wash water temperature of 85°F. and a wash water rate of 24-in. of vertical rise per minute he expanded the sand 33%, whereas, with a temperature of 33° F. and

[2]John R. Baylis. Water Works & Sewerage, **83**, No. 9 (1935).
[3]Edward S. Hopkins. Water Purification Control. Williams & Wilkins Co. (1932).
[4]W. C. Lawrence. Jour. A. W. W. A., **24**, No. 9 (1932).
[5]J. Clark Keith. Jour. A. W. W. A., **24**, No. 7 (1932).
[6]George F. Gilkinson. Proc. 9th. An. Kansas Water Works School.

the same rate of rise the expansion was 53%, also that no benefits were gained by expanding the sand in excess of 40%.

Baylis[2] advocates the use of surface wash followed by a 35% sand expansion for keeping the sand bed clean. Herbert E. Hudson, Jr.[7] of the Chicago Experimental Filtration Plant concurs with Baylis.

The repeated mention of definite percentage of sand expansion by the advocates of the different methods of back washing filters shows the necessity of a practical instrument for measuring and indicating the degree of sand expansion. In our opinion it would be desirable to have a permanent record of the length of filter wash as well as of the velocity of wash water applied.

Apparatus and Methods

Description of Apparatus. The meter furnished by the Simplex Valve & Meter Co. (Fig. 1) consists of a dial graduated in inches, and an index pointer and pulley. The cone shaped float, made after the specifications of Herring, was 14 in. in diameter and 4 in. high, the angle at the base being 25 degrees. Sheet lead for loading the float was attached to the base with bolts. This cone had a one inch skirt beyond the base. The specifications included six or eight $\frac{1}{8}$-in. holes through the skirt of the float to prevent trapping of air. The weight of float and counterweight was adjusted to allow the float barely to sink through the water. When this float was installed in one of our filters it was immediately apparent that the angle of the cone was too shallow, since the expanding sand lodged on the surface of the cone. The additional weight of the sand caused the float to sink into the expanded sand defeating the function of the instrument.

It was therefore necessary to design a new float with an angle slightly greater than the angle of repose of the material in the filter. This float also had a base of 14 in., but the angle at the base was 52 degrees. No sand was retained on the surface of this cone. Since the float was 9 in. in height, it was not a practical instrument, because, if the sand was expanded to within a distance of less than 9 in. of the trough overflow, the apex of the float protruded above the surface of the water upsetting the balance of the counterweight to the float, and in reality lowering the freeboard. Working with this float in the large filter revealed the fact that the float method of measuring sand expansion is more accurate than the submarine light method.

Experimental Filter. Since the object of this study did not necessitate the filtration of water, but was limited to back washing only, we found it convenient to convert an aquarium into a filter. This filter had three sides of glass and one of wood, affording ample opportunity

[7]Herbert E. Hudson Jr. Jour. A. W. W. A. **27**, No. 11 (1935).

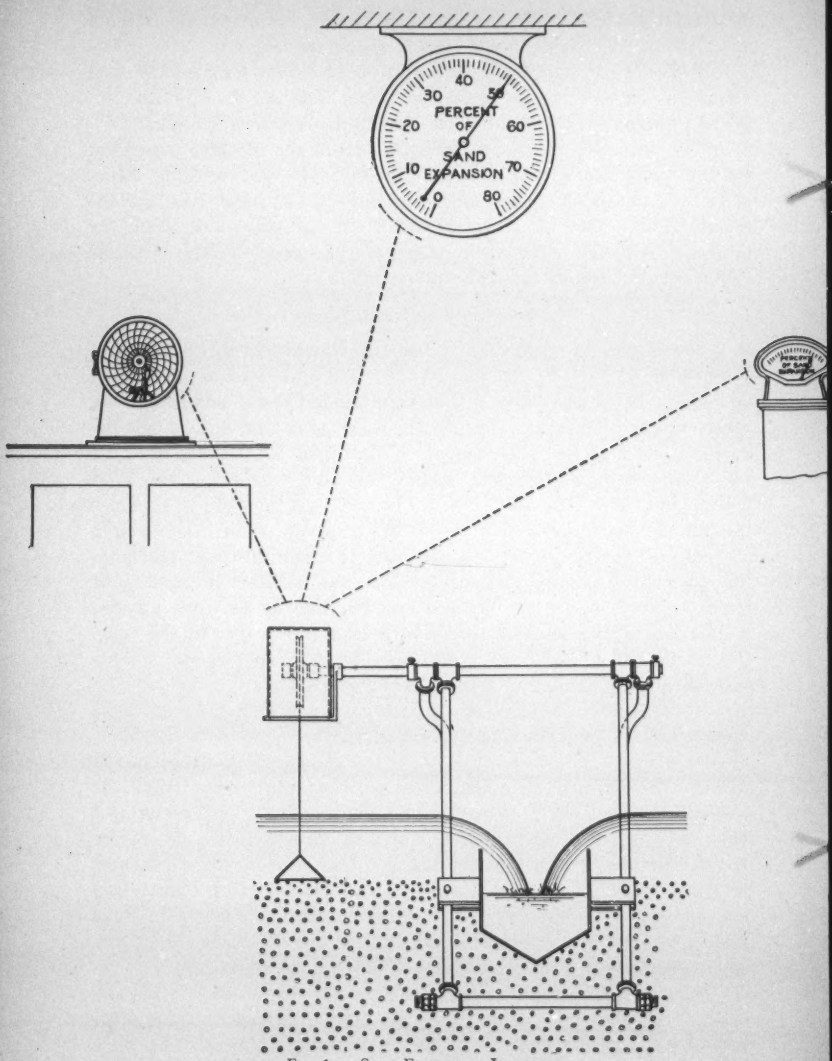


FIG. 1 — SAND EXPANSION INDICATOR.

for observing the movement of the sand bed during the wash. The wooden side made it convenient for introducing ½-in. pipe underdrains and attaching a tin gutter to serve as a wash-water trough. The half-inch pipe in the bottom of the filter was in the form of a cross with plugged ends. The bottom of the pipe was perforated with a sufficient number of ⅛ in. holes to correspond with the area of the pipe, and a half-inch valve was placed in this pipe at a convenient place for the control of the wash water. The inside dimensions of the filter were 6⅝ in. by 9⁴/₅ in. by 41 in.

The gravel in the filter was composed of the following sizes and depths:

(1) A 3-in. layer from ⅝ to ⅜-in. in size.
(2) A 2-in. layer from ⅜ to ⅛-in. in size.
(3) A 2-in. layer from ⅛ to 1/32-in. in size.

The gravel was kept in place by a fixed screen. The depth of sand in the filter was limited to 20 in. in order to leave a space of 13.5 in. between the settled sand bed and the wash-water trough. The 13.5 in. of freeboard made it possible to expand the sand bed 60%. The sand, zeolite and coal used in the tests were as follows:

Material	Source	Effective Size	Uniformity Coefficient
Sand (9 years in filter)	Allentown Filters	0.64 mm.	1.30
Clean sand	Roberts Filter Mfg. Co.	0.40-0.45 mm.	1.60
Anthrafilt	Anthracite Institute	0.60-0.75 mm.	1.60
Zeolite (greensand)	Zeolite Sales Co.		

The angle of repose for the expanded sand, coal and zeolite was determined by the use of floats with base angles of 35, 40, 43, 45, and 51.4 degrees. The 45 degree float was satisfactory for the sands used in the tests, while a 51.4 degree float was required for the coal and zeolite.

The accompanying table shows the characteristics of the floats used in the experiment. These, with the exception of float A, were made with a convex base and loaded on the inside with lead. Float A was made with a ⅛-in. skirt at the base and loaded with sheet lead attached to the base.

During the test with the model filter, we found that with a correct counterweight, the float followed the sand very closely and that when the specific gravity of the float was greater than 1.7, there was no tendency for the float to revolve or to be displaced sidewise. Figure 2 shows the relation between the rise of the sand in inches as given by the indicator, and the actual rise of the sand as measured with a scale placed against the glass side of the filter. It will be noted from these curves that if the counterweight is too light, *i.e.*, the float is too

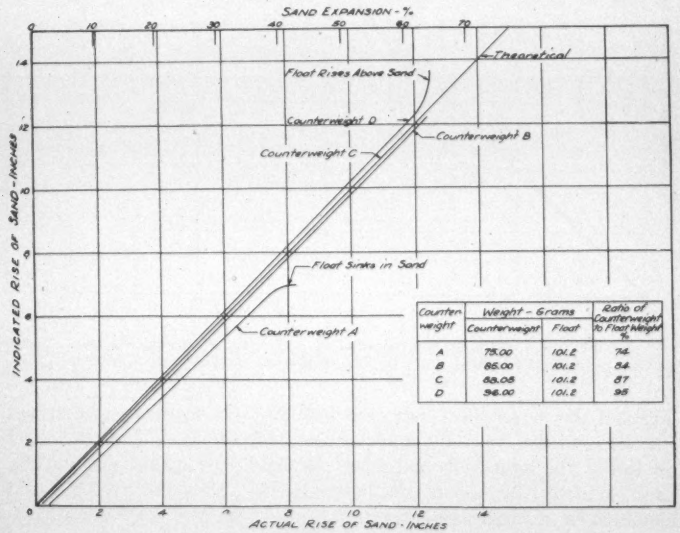
EXPERIMENTAL FLOAT DATA

Float Letter	Approximate Size of Float Millimeters		Angle at Base Degrees	Volume of Float Milliliters	Wt. of Float in Water Grams	Wt. of Counterweight Grams	Specific Gravity of Float	Percentage Counter weight*	Material in Filter
	Base	Height							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
A	78	50	51.4	79.2	101.2	88.05	2.263	87	Sand
B	78	34	40						
C	78	27.5	35						Sand
D	78	40	45	70.9	118.51	106.37	2.671	89.7	Sand
E	100	50	45	153.6	44.9	27.23	1.29	60.6	Sand
F	100	50	45	147.2	61.67	40.44	1.418	65.6	Sand
H	100	50	45	147.9	87.67	63.67	1.592	72.6	Sand
I	100	50	45	142.0	108.55	92.0	1.764	84.8	Sand
K	100	50	45	147.9	119.81	105.65	1.809	88.2	Sand
L	100	50	45	145.3	183.33	168.85	2.262	92.1	Sand
M	100	50	45	151.9	152.8	137.62	2.005	90.1	Sand
N	100	50	45	130.5	159.9	143.94	2.226	89.9	Sand
O	100	50	45	154.7	159.5	145.49	2.03	92.9	Sand
P	100	50	45	139.5	182.4	163.97	2.308	89.9	Sand
						121.9		90.3	Coal
R	100	64	51.4	174.9	135.03	123.26	1.772	93.5	Zeolite
						128.46		95.1	Sand
S	78	36.5	43						

Floats B, C, and S—Angles at base too small..
*100 x Column (7) ÷ Column (6).

heavy, that the rise as shown by the indicator gradually falls below the actual rise. This lag increases until finally the float sinks completely in the sand. It is also shown that if the counterweight is too heavy, *i.e.*, the float is too light, that the rise as shown by the indicator gradually increases above the actual sand rise until a point is reached when the float rises completely above the sand and remains in suspension.

The table on Figure 2 shows the actual weights of the counter-



Counterweight	Weight - Grams		Ratio of Counterweight to Float Weight %
	Counterweight	Float	
A	75.00	101.2	74
B	85.00	101.2	84
C	88.05	101.2	87
D	98.00	101.2	98

FIG. 2 — TESTS OF SAND EXPANSION INDICATOR IN MODEL FILTER. EFFECT OF VARIATION IN WEIGHT OF COUNTERWEIGHT.

weights and the weight of the float in water, as well as the percentage that the counterweight is of the float weight. From this table we see that the best agreement is obtained with the counterweight weighing approximately 87% of the float weight.

Figure 3 shows the tests made with the 87 per cent counterweight. In it will be noted that no readings have an error greater than ± 2%. This Figure also shows the lag of the float, since the test was made by increasing the washing rate until a 12-in. expansion was obtained and then decreasing the washing rate to zero.

All of the tests indicate that the Sand Expansion Indicator is probably the best means for actually measuring the sand expansion.

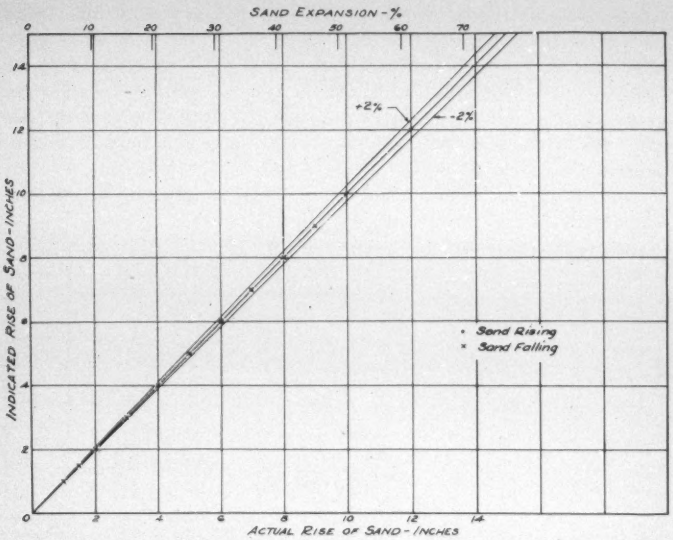


FIG. 3 — TESTS OF SAND EXPANSION INDICATOR IN MODEL FILTER. COUNTERWEIGHT EQUAL TO 87% OF WEIGHT OF FLOAT IN WATER.

Tests of the model filter indicated that the light method of determining the sand rise was only approximate, since the sand tends to collect on top of the light bulb and when the light just strikes through the sand, actually, the top of the bulb may be above the average sand elevation by a small amount.

Most of the tests were made with wash water at 62° F. Identical results were obtained when temperatures were 40° and 80° F.

The accompanying table shows that the correct counterweight percentage for sand with float R was 90.3%. With the same float when coal was used in the filter, 93.5% of the float weight in water was the correct percentage weight of the counterweight and with Zeolite (greensand) 95%. This shows that the specific gravity of the material in the filter has a definite relation to the counterweight.

SUMMARY

Authorities quoted appear to be washing filter beds at a percentage sand expansion which has proved to be most economical and efficient in their plants.

A practical instrument, consisting of a float, counterweight and indicator, for indicating the actual filter bed rise, is described.

It is shown that the meter is accurate and stable irrespective of the particle size of the filtering medium, temperature and depth of sand bed.

The process of filter washing, by a group of operators working with the same beds, can be standardized, in so far as definite sand expansion is concerned, by the use of a sand expansion meter.

The authors acknowledge the valuable service rendered by Mr. Sweeten, Experimental Engineer of the Simplex Valve & Meter Co. in the tests and in the preparation of this paper.

BATHING IN PUBLIC WATER SUPPLY TRIBUTARIES CONNECTICUT SUPREME COURT DECISION

The question of the right to bathe in streams tributary to public water supplies is one that has been the subject of interest and concern to members of the New England Water Works Association. Therefore, it is believed that the following decision recently rendered by the Connecticut State Supreme Court will be of value for reference. The facts of the case and the law in question are stated in the decision.

State of Connecticut vs. William Heller
Fairfield County, October Term, 1937.

Information charging the defendant with the crime of bathing in a stream tributary to a reservoir, brought to the Criminal Court of Common Pleas for Fairfield County, where a demurrer to the information was overruled and the issues were tried to the court, Dwyer, Judge; judgment of guilty and appeal by the defendant. No error.

William Hanna, for the appellant (defendant).

Richard S. Swain, Prosecuting Attorney, for the appellee (the State).

Brown, Justice. The information charged that the defendant on or about July 11, 1936, at Easton, bathed in a stream tributary to a reservoir from which the inhabitants of Bridgeport are supplied with water, in violation of Sec. 2542 of the General Statutes. That statute so far as relevant provides: "Any person who shall bathe in any reservoir from which the inhabitants of any town, city or borough are supplied with water, or in any lake, pond or stream tributary to such reservoir," shall be subject to fine, imprisonment, or both. The defendant's demurrer to the information was overruled. He thereupon elected to be tried by the court and it found him guilty.

These facts are undisputed: On July 11, 1936, the defendant owned in fee simple a tract of land in Easton comprising about 38 acres, on which was a dwelling-house occupied by him and his family. Ball Wall Brook flows across this land forming a small pond thereon, and runs on into the Aspetuck Reservoir about 4,200 ft. away, from which by connecting pipe water flows into the Hemlock Reservoir. These reservoirs are part of the Bridgeport Hydraulic Company's system, from which Bridgeport and other municipalities are supplied with water. Ball Wall Brook is and ever since before the defendant's purchase of his property has been a stream tributary to both of these

reservoirs. The distance from the place where it enters the Aspetuck Reservoir to the pipes leading from the reservoir to the municipality is over 3½ miles. The combined area of the reservoirs when full is about 500 acres. On July 11, 1936, the accused bathed in Ball Wall Brook at a place within the boundaries of the 38-acre tract owned by him, and was arrested and charged with a violation of Sec. 2542 of the General Statutes.

The fundamental question determinative of the appeal is whether Sec. 2542 as applied to the defendant in forbidding his bathing pursuant to his property right in a brook flowing through his own land, is a valid exercise of the State's police power, or is unconstitutional as depriving him of property rights without compensation. It is unquestioned that the defendant as riparian owner had a right which included ordinary and reasonable bathing privilege in this brook by himself, his family, and inmates and guests of his household. *Harvey Realty Co. v. Wallingford,* 111 Conn. 352, 359, 150 Atl. 60. It is further undisputed that Sec. 2542 can only be sustained as an exercise of the State's police power. Furthermore, it is not disputed that the object of the statute in question is to protect the health of citizens using water distributed through these reservoirs, and that thus its purpose affords a proper basis for the exercise of the police power inherent in the Legislature. *State v. Racskowski,* 86 Conn. 677, 680, 86 Atl. 606; 1 Farnham, Waters and Water Rights, p. 618, Sec. 137a. The issue for determination, therefore, is reduced to the sole question of whether or not this exercise of the police power for the purpose indicated, is so unreasonable as to violate the provisions of Section 11 of Article I of the Constitution of the State of Connecticut or Section 1 of Article XIV of the Amendments to the Constitution of the United States.

The foundation of the police power of a State is the overruling necessity of the public welfare. Thus it has been referred to as that inherent and plenary power which enables the State "to make and enforce rules and regulations concerning and to prevent and prohibit all things hurtful to the comfort and welfare of society. It has been aptly termed 'The law of Overruling Necessity,' and compared with the right of self-protection of the individual, it is involved in the very right and idea of government itself, based on the two maxims that, 'The Public Welfare is the Highest Law,' and that 'One must so use his own right as not to injure that of another'." 1 Bruce, State and Federal Control of Personal and Property Rights, 8. Accordingly all property of every person is owned subject to this power resting in the State. It is an incident of title. *Application of St. Bernard Cemetery Association,* 58 Conn. 91, 96, 19 Atl. 514. "The power to legis-

late for the safety, health or welfare of its people, is inherent in the State by virtue of its sovereignty. All property is held subject to this power, *Meriden v. West Meriden Cemetery Association,* 83 Conn. 204, 207, 76 Atl. 515. And all property, too, is held upon the implied promise of its owner or user that it shall not be used against the public welfare." *Connecticut Co. v. Stamford,* 95 Conn. 26, 29, 110 Atl. 554.

It is pursuant to these principles that the State may regulate one's use of his property. "In short, it (the police power) may regulate any business or the use of any property in the interest of the public health, safety or welfare, provided this be done reasonably. To that extent the public interest is supreme and the private interest must yield. Eminent domain takes property because it is useful to the public. The police power regulates the use of property or impairs the rights in property, because the free exercise of these rights is detrimental to public interest. Freund, Police Power, Sec. 511." *Windsor v. Whitney,* 95 Conn. 357, 367, 111 Atl. 354; *State v. Kievman,* 116 Conn. 458, 463, 165 Atl. 601. "The use of property may be regulated as the public welfare demands. . . . Beyond this, private property cannot be interfered with under the police power, but resort must be had to the power of eminent domain and compensation made." 1 Lewis, Eminent Domain (3d Ed.) p. 492, Sec. 249. "The protection of the public safety, health or morals, by the exercise of the police power, is not within the inhibition of the Constitution. And since all property is held subject to such regulation, there is no obligation upon the State to indemnify the owner of property for the damage done him by the legitimate exercise of the police power. Property so damaged is not taken; its use is regulated in order to promote the public welfare." *Connecticut Co. v. Stamford, supra,* 30; *State v. Wheeler,* 44 N. J. L. 88, 91.

But there are definite limits upon the application of the foregoing principles. "The power of regulation by government is not unlimited; it cannot, as we have stated, be imposed unless it bears rational relation to the subjects which fall fairly within the police power and unless the means used are not within constitutional inhibitions. The means used will fall within these inhibitions whenever they are destructive, confiscatory, or so unreasonable as to be arbitrary. *Euclid v. Ambler Realty Co.,* 272 U. S. 365, 47 Sup. Ct. 114." *State v. Hillman,* 110 Conn. 92, 105, 147 Atl. 294. "A large discretion is necessarily vested in the Legislature to determine not only what the interest of public health, security and morals require, but what measures are necessary for the protection of such interests. *Young v. Lemieux,* 79 Conn. 434, 440, 65 Atl. 436, 600."

Cotter v. Stoeckel, 97 Conn. 239, 244, 116 Atl. 248. Furthermore, " 'incidental damage to property resulting from governmental activities, or laws passed in the promotion of the public welfare, is not considered a taking of the property for which compensation must be made.' " *State v. Hillman, supra,* 104.

The foregoing principles are established by abundant authority. The difficulty arises in their application, to determine where the proper exercise of the police power ends and that of the other governmental power of eminent domain begins, that is, how far the State can properly go to deprive an owner of valuable rights under the former without compensation, as distinguished from necessary resort to the latter with compensation. The right of the State in the exercise of its police power to limit the use of property even when prejudicial to the pecuniary interests of the owner, has been made increasingly clear by our more recent decisions. *Windsor v. Whitney, supra; State v. Hillman, supra; Young v. West Hartford,* 111 Conn. 27, 149 Atl. 205; *Rice v. Zoning Board of Appeals of Milford,* 122 Conn. 435, 190 Atl. 257. Whether a statute enacted pursuant to the police power is a means reasonable in quality and extent, and in time, place and circumstance, presents a question to be determined by the court. *Windsor v. Whitney, supra,* 369. It is the court's duty in such case, in the exercise of great care and caution, to make every presumption and intendment in favor of the validity of the statute, and to sustain it unless its invalidity is beyond a reasonable doubt. *Beach v. Bradstreet,* 85 Conn. 344, 350, 82 Atl. 1032; *State v. Lay,* 86 Conn. 141, 145, 84 Atl. 522; *State v. Nuolo,* 119 Conn. 323, 325, 176 Atl. 401. It is in the light of the principles above stated, that we must determine whether the provisions of Sec. 2542 are so unreasonable as to constitute an unconstitutional invasion of the defendant's rights.

The defendant claims the statute is invalid in that its unlimited scope constitutes an unreasonable exercise of the police power, it being contended that it goes far beyond what is necessary to accomplish the legislative purpose and so does not bear a reasonable relation thereto. Thus it is contended that since by its terms the statute prohibits bathing in "any tributary" of a reservoir, it could apply to one bathing in a brook which finally flows into a reservoir a hundred miles away but that any resulting pollution would be cleared before the polluted water reached such reservoir and that therefore it prohibits something unnecessary for the public's protection. The physical impossibility of such a case, due to the boundaries and topography of the State, affords one answer to this argument. The lack of a finding that the pollution would be cleared under such circumstances affords another; while the established scientific fact that water can

serve as a carrier of disease germs to one drinking it, is one within judicial notice (*State v. Morse,* 84 Vt. 387, 80 Atl. 189, 194), what the conditions essential to the destruction of such germs in water of a flowing stream may be, is not. But aside from this, the tendency of such pollution to produce public injury, even though no actual injury occurs, affords grounds sufficient to sustain the Legislature's act. *State v. Wheeler, supra,* 92; *Dunham v. New Britain,* 55 Conn. 378, 384, 11 Atl. 354. Upon the record before us we cannot hold that bathing in a tributary of a reservoir might not have such a tendency to endanger the health of users of the water that the Legislature might not reasonably prohibit it. It is our conclusion that the statute by its terms is not of such broad scope that it fails to bear a rational relation to the protection of the public health, thus constituting an unreasonable exercise of the police power.

The defendant further claims the statute is invalid because it deprives him of a property right without compensation. One contention is that the Bridgeport Hydraulic Company by the operation of this penal statute is obtaining rights in his property without paying for them. The State chartered the company to engage in business as a public utility to supply water for profit to the municipalities served. If the sole result from the enforcement of Sec. 2542 was to benefit this company, there would be force to the defendant's contention, for the valid exercise of the police power must find justification in the general public welfare rather than in the protection or enhancement of private interests. *State v. Kievman, supra,* 469. The significant fact here is, however, that by the State's grant of a charter to the company to supply water for the people in this locality, the State's duty to protect the health and welfare of these people was neither abandoned nor discharged. Therefore, the fact that the State's enactment of such a statute in carrying out its duty, incidentally benefits the company by helping to safeguard the purity of its water supply, which it as a public agent under its charter dispenses to meet the needs of the people of the locality, is of no consequence. The duty of the State is in extent statewide, and Sec. 2542 is of application coincident therewith.

The further and basic contention is, that since this statute entirely deprives the defendant of his valuable property right of bathing in this stream, it goes beyond regulation within the police power, and constitutes a taking, warranted only under eminent domain proceedings with proper compensation. The principles above recited make clear that this conclusion does not necessarily follow. Of the legion of decisions illustrative of this, we refer to but two cases very closely analogous to the present, *Commonwealth v. Tewksbury,* 52 Mass. 55,

57, and *People v. Bridges,* 142 Ill. 30, 31 N. E. 115, 16 L. R. A. 684, 687. In the former, a statute for the protection of Boston Harbor, forbidding any person to take stones, gravel, or sand from the shore, was sustained as against one taking where he owned the fee, as was the statute in the latter forbidding any person to fish with a seine in a stream or lake, even as against an owner fishing upon his own land. Thus a law which in fact in certain respects deprives the owner of use of his property, if to protect a common right of all citizens, is valid within the police power. *State v. Wheeler, supra. A fortiori* regulation depriving the defendant merely of his property right to bathe as here, may also be valid as within it. What we said in *State v. Hillman, supra,* 105, is a sufficient answer to this contention of the defendant: "Regulation may result to some extent, practically in the taking of property, or the restricting of its uses, and yet not be deemed confiscatory or unreasonable.

There is no distinction in principle between the legal restriction in the present case which without compensation deprives the owner of his right to bathe in the stream crossing his property, and that in *State v. Hillman, supra,* prohibiting the use of property for business purposes; or that in *Windsor v. Whitney, supra,* depriving him of the right to build on the entire area of his lot; or that in *Ingham v. Brooks,* 95 Conn. 317, 328, 111 Atl. 209, denying an owner the right to move a building from one place to another, which was held within the police power although the ordinance in question was void by reason by the arbitrary and unfettered discretion in the town officials thereunder, or that in *Application of St. Bernard Cemetery Association, supra,* denying an owner the right to use its property for cemetery purposes unless the court determined such use would not be detrimental to public health; or those in a number of cases that have come before us involving various zoning ordinances. The restriction imposed by Sec. 2542 was not a taking contravening any constitutional provision, but rather a regulation within the State's police power.

Two decisions, where the precise question here presented on substantially the same factual situation was determined, have reached diametrically opposite conclusions. In the earlier case of *People v. Hulbert,* 131 Mich. 156, 173, 91 N. W. 211, decided in 1902, where the defendant, a riparian owner on a pond or lake from which a city took its water supply, was convicted of bathing therein, under a statute which made it a criminal offense to pollute such waters, the court held in a very brief statement citing no authorities that as such owner the defendant had a right to reasonable use of the waters of the lake including the right to bathe and swim therein, and that he could not

be deprived of this right by the police power of the State. The later case of *State v. Morse, supra,* decided in 1911, on a similar state of facts, criticized the earlier case and arrived at the opposite conclusion. In the case of *Battle Creek v. Goguac Resort Association, Ltd.,* 181 Mich. 241, 148 N. W. 441, 443, decided in 1914, in an opinion concurred in by three of the judges of the equally divided court, some question is intimated as to the soundness of the court's decision, in the Hulbert case.

In the Morse case the court pointed out that since the defendant's right to bathe conflicted with the public's rights concerning its health, safety, and welfare, the former must yield and the latter prevail, and that the enforcement and protection of these paramount rights is the proper function of the police power. It went on to conclude that within the principles definitive of the police power and those applicable to the interpretation of enactments pursuant thereto, which we have already mentioned, the action of the state board of health in question was a valid exercise of the police power. We reach a similar conclusion in the case before us. What the court says in the Morse case (p. 393) well states the effect of the statute here: "Such use in such circumstances may be prohibited in a valid exercise of the police power. The owner's rights are not then 'taken' in a constitutional sense; or, if this statement savors too much of refinement of reasoning, as some suggest, the 'taking' is not such as the Constitution prohibits. The beneficial use of the property is curtailed in some measure but all the other incidents of ownership are left unimpaired. The fact that this is a property right does not determine the question." The regulation imposed by Sec. 2542 is neither destructive, confiscatory nor arbitrary, but is on the contrary upon all the facts in the case, reasonable in time, place, and circumstance, and therefore a reasonable exercise of the police power; *Cf*: *State v. Griffin,* 69 N. H. 1, 22, 39 Atl. 260; *Miles City v. State Board of Health,* 39 Mont. 405, 411, 102 Pac. 696; *Durham v. Cotton Mills,* 141 N. C. 615, 634, 54 S. E. 453.

The defendant makes one further claim, that other statutes, including Sections 2539, 2540 and 2541, show so clearly that the legislative policy of the State is to provide for compensation in all cases where a person is to be deprived of any property rights in protecting public water supplies, that Sec. 2542 must in any event, for that reason, be interpreted as not applicable to one like the defendant, bathing in a reservoir tributary within the limits of his own land. Section 2539 provides for injunctive relief against the pollution of a reservoir, and authorizes the abatement of nuisances upon a watershed causing such pollution. It further gives the owner a right to compensation "for all

unnecessary or unreasonable damage done" to his property by those abating a nuisance thereunder. Section 2540 provides for the assessment of damages in favor of one damaged or deprived of "any substantial right" by any order of the court under Sec. 2539. Section 2541 provides for the taking of property for the establishment or protection of a public water supply, and the awarding of damages therefore "in any case in which the law shall require compensation." Under these statutes by the court's decree, not only may an owner's rights to use his property be curtailed, but his very title to either a part or all of it may be entirely divested. The Legislature, therefore, in these sections with good reason, made provision for compensation to meet such a contingency, but by its enactment of penal Sec. 2542 under which at most one's right to bathe in a stream on his land could be cut off, did not. This, as well as the language above quoted from Sections 2539, 2540 and 2541, refutes the defendant's claim that they evidence a legislative policy to provide compensation in all cases where private property rights are restricted for the benefit of a public water supply. These indicate rather that the Legislature contemplated there would be cases where the exercise of the police power would interfere with one's use of his property without entitling him to compensation.

There is no error.

In this opinion the other judges concurred.

The defendant appealed to the Supreme Court of the United States, but this Court refused to review the case, ruling that there was no "subtantial Federal question" involved.[1]

[1]New York Herald-Tribune, April 5, 1938.

WATER WORKS FUNDS FOR WATER WORKS PURPOSES

BY LELAND G. CARLTON*

[*Read September 24, 1937.*]

Whenever the question is raised how water works funds should be used there are always two definite points of view that are brought out in the discussion. The first is that all revenue should be turned over to the general fund of the city or town, the second is that all revenue should be used solely for water works purposes. The latter view is the one usually advanced by water works officials and is the one that is to be dealt with here.

One of the major problems with which a town or city has had to contend in recent years, perhaps the major problem, is to raise sufficient revenue to meet its current expenses. Tax rates have had to be increased to a point where the next straw might break the camel's back, with the result that any available funds, regardless of their nature, have been coveted to reduce this load.

One source of these available funds has been the surplus that certain water works have been able to accumulate, and many instances can be cited where this surplus, or part of it, has been transferred to the general fund with a resulting curtailment of essential departmental activities. Another source has been created by having all water works revenue paid into the general treasury and by appropriating a lesser amount to be expended by the water works, thereby leaving the remainder for general expenses.

Last year This Association appointed a special committee to study this situation and determine if a general bill could not be prepared and presented to the Legislature which would provide that all water works revenue should be used for water works purposes. This committee is known as the Massachusetts Water Finance Law Committee, of which Roger W. Esty is chairman. This committee held several conferences but was finally advised that this was not the proper time to present such a bill as it would undoubtedly fail to pass the Legislature.

It is encouraging to note, however, on examining the Acts and Resolves passed by the General Court of Massachusetts during recent years, that the legislatures were of the opinion that water works revenue should be held for water works purposes. To substantiate this, take for instance the Acts of 1906, Chapter 317, authorizing the City of Springfield to increase its water supply. Section 9 of this Chapter reads as follows:

*Registrar, Municipal Water Works, Springfield, Mass.

The income of the water works shall be applied to defraying all operating expenses, interest charges and payments on the principal as they accrue upon any bonds or notes issued under the authority of this act or of previous acts relating to the water supply of the city. If there should be a net surplus remaining after providing for the aforesaid charges it may be used for such new construction as the water commissioners, with the approval of the city council, may determine, and, in case a surplus should remain after payment for such new construction, the water rates shall be reduced proportionately.

While this requires that the city council must approve of the use of any surplus for new water works construction, it does not allow the funds to be appropriated for anything else.

A section very similar to the one just quoted has been accepted as a standard and has been incorporated into many special acts dealing with the water supplies of towns and fire districts in Massachusetts, the difference being that the approval must be made by the town and that "no money shall be expended in new construction by the water commissioners except from the net surplus aforesaid unless the said town appropriates and provides money therefore."

There are a few cases in which this section not only requires that the rates shall be such as to provide for the operating expenses, etc., but shall also provide for an additional amount not to exceed a definite figure per year for new construction, but in no case are the funds to be used for anything but water works purposes.

A very interesting case has been recently decided in the Supreme Court of Ohio. The city council of Lakewood voted to transfer $70,000 of water works funds to the general fund. This action was approved by the mayor and also by the Commissioner of Taxation. Later a citizen took this action to court on the ground that water rates were, as a matter of fact, taxes that were collected for a definite purpose and therefore must be used or held for the purpose for which they were collected. The case was carried through all of the courts to the Supreme Court, where a decision was rendered that the money must be returned to the water works.

Following along these same lines, a certain town in Western Massachusetts has recently asked its solicitor for an opinion on whether the town can legally transfer water works funds to the general treasury. This may eventually result in a similar case being tried in Massachusetts.

PROCEEDINGS

NOVEMBER 1937 MEETING

Hotel Statler, Boston, Mass.

Thursday, November 18, 1937

President Warren J. Scott in the Chair.

The President anounced the death of Horace Kingman, Superintendent of the Brockton, Mass., Water Department.

Secretary Gifford announced the election by the Executive Committee of the following *Members*: Thomas F. Monahan, Haverhill, Mass.; James J. Kehoe, Saxonville, Mass.; Francis E. Blaney, Salem, Mass. Associate: Cohoes Rolling Mills Company, Cohoes, N. Y. (Reinstated).

A paper "Preparing and Packaging Liquid Chlorine and Allied Products for Water Plants," illustrated, was read by L. L. Hedgepeth, Manager, Technical Service Department, Pennsylvania Salt Manufacturing Company, Philadelphia, Pa. Donald C. Calderwood, Roger W. Esty and Linn H. Enslow took part in the discussion.

A paper "Methods of Providing Proportional Feed of Chemicals in Water and Sewage Plants," illustrated, was read by Rudy P. Lowe, Vice-President and Chief Engineer, Proportioneers, Inc., Providence, R. I.

A paper "Relining a Storage Reservoir with Gunite," illustrated, was read by Roger W. Esty, Superintendent, Danvers Water Works, Danvers, Massachusetts. Donald C. Calderwood and Horace M. King took part in the discussion.

DECEMBER 1937 MEETING

Hotel Statler, Boston, Mass.

Thursday, December 16, 1937.

President Warren J. Scott in the Chair.

The President announced the loss by death of the following members: Charles R. Bettes, General Manager of the Long Island Water Company; Robert A. Cairns, City Engineer of Waterbury, Conn.; David A. Heffernan, Superintendent of Water Service, Milton, Mass., a Past-President of the Association.

Secretary Gifford announced the election by the Executive Com-

mittee of the following: *Members*: Robinson D. Buck, Civil Engineer, Hartford, Conn.; Allan T. Gifford, Instructor in Hydraulics and Water Power Engineering, M. I. T., Cambridge, Mass.; Clarence Henry Reed, Assistant Sanitary Engineer, Metropolitan District Commission, Framingham. *Associate*: National Gunite Contracting Company, Boston, Mass.

A paper "Steel Pipe for Water Mains," was read by E. H. Thwaits, Consulting Engineer, Water Works Division, Youngstown Sheet and Tube Company, Youngstown, O. The paper was supplemented by moving pictures. Sidney S. Anthony discussed the paper.

A film showing microörganisms, made by J. B. Hawley of Hawley, Freese and Nichols, Consulting Engineers, Fort Worth, Texas, and lent through the courtesy of Harry J. Krum, City Chemist and Bacteriologist, Allentown, Pennsylvania, was presented and explained by Melville C. Whipple, Assistant Professor of Sanitary Chemistry, Harvard Graduate School of Engineering, Cambridge, Mass.

A paper "The New Sand Wash Brook Dam and Reservoir at Pittsfield, Massachusetts," was read by Samuel M. Ellsworth, Consulting Engineer, Boston, Mass.

January 1938 Meeting

Hotel Statler, Boston, Mass.

Thursday, January 20, 1938

President Warren J. Scott in the chair.

Secretary Gifford announced the election by the Executive Committee of the following: *Members*: Harold B. Scales, Chemist and Bacteriologist, Portland Water District, Portland, Me.; Charles A. Root, City Engineer, Waterbury, Conn. *Associate*: Brown Company (William H. Barry, Chemical Division Manager), Portland, Me.

Professor Ernest A. Hauser, Massachusetts Institute of Technology, Cambridge, gave a talk on "New Developments in the Chemistry of Rubber and Like Substances in Relation to Water Works Practice."

A paper "Rubber and its Uses in Water Works," was read by J. C. Walton, Technical Superintendent, Boston Woven Hose and Rubber Company, Cambridge, Mass.

A paper on "Cathodic Protection—Combating Pipe Corrosion with Electricity," was read by A. V. Smith, Electrolysis Engineer, United Gas Improvement Company, Philadelphia, Pa.

A paper "Economics Involved in the Selection of Pumping Equipment," was read by David D. Eames, Consulting Engineer, Boston, Mass.

February 1938 Meeting

Hotel Statler, Boston, Mass.

Thursday, February 17, 1938.

President Warren J. Scott in the chair.

Secretary Gifford announced the election by the Executive Committee of the following: *Members*: Clarence S. Ball, P.W.A. water system agent in charge of Northbridge Water Works, Whitinsville, Mass.; Forrest D. Bradshaw, Superintendent, South Sudbury, Mass.; Frederick W. Peet, Manager, Hazardville Water Company, Hazardville, Conn.; Truman H. Safford, Hydraulic Engineer with Charles T. Main Co., Boston, Mass.; Roscoe H. Suttie, Associate Professor of Civil Engineering, Yale University, New Haven, Conn. *Associate*: Devonshire Arctic Chemical Co., Boston, Mass.

A paper "The Need of Improvements in the Distribution System of the Metropolitan Water District," was read by Eugene C. Hultman, Chairman, Metropolitan District Commission and the Metropolitan District Water Supply Commission, Boston, Mass. The paper was discussed by Messrs. Arthur D. Weston, Gordon M. Fair, and Charles W. Sherman.

A paper "Main Pipe Assessment Methods," was read by Warren A. Gentner, Metropolitan District Commission, Water Bureau, Hartford, Conn.

DAVID A. HEFFERNAN

November 24, 1937, marked the death of David A. Heffernan after a short illness at his Milton home. He was respected by all those who knew him as one of the finest and kindliest gentlemen in the water works profession.

He was born in Dedham, Massachusetts, April 16, 1869, the son of Thomas and Ellen Keefe Heffernan. In 1889, he went to work as a plumber's helper for the Brush Hill Water Company, a local company buying water from the Hyde Park Water Company, and serving a limited section of the town of Milton. Somewhat later, the pipes were extended to serve a larger part of the town and the company was reorganized as the Milton Water Company. In 1902 the works were taken over by the Town of Milton, and Mr. Heffernan became the Superintendent of the Milton Water Department—a position which he held until his death.

On November 12, 1902, he became a member of the New England Water Works Association. He was a regular attendant at its meetings, and soon became widely known. He was neither afraid to ask questions, nor to contribute information or opinions. He served on many committees of the Association, including a committee on the Standardization of Brass Fittings, of which he was Chairman. This committee continued to function from 1923 to 1937, and coöperated with a similar committee of the American Water Works Association, but had not made any formal report.

Mr. Heffernan was President of the New England Water Works Association for the year 1923-1924. He contributed the following papers to the Association's Journal:

Low Consumption of Water in the Town of Milton. (1914, p. 290)

Thawing Out Frozen Service. (1918, p. 133)

Practical Methods of Detecting Leaks in Underground Pipes. (1918, p. 204)

Some Practical Suggestions to Water Works Officials, of Benefit to the Consumer. (1920, p. 183)

Water Distribution in Connection with Plumbing and Action of Water on Metal. (1921, p. 123)

Service Pipes and Plumbing Appliances: Some Experiences, Experiments and Recommendations. (1923, p. 47)

Reminiscences of a Superintendent. (1928, p. 235)

The Dexter Brackett Memorial Medal was awarded to him for the paper, "Practical Methods for Detecting Leaks in Underground Pipes," which was selected as the best paper presented in 1918.

Mr. Heffernan was also a member of the American Water Works Association and had been chairman of its New England section.

In addition to his work for the Water Department, Mr. Heffernan had served the Town of Milton in many other ways. He was secretary of the Milton Planning Board from the time it was formed, about twenty years ago. He was also a Trustee of the Milton Savings Bank, and a Director of the Milton Coöperative Bank.

Mr. Heffernan is survived by his wife, who was Miss Catherine McDermott.

"Dave" Heffernan, as he was affectionately called by almost everyone who knew him, was a good citizen, a faithful and efficient public servant, and a good friend to many people. His life is a fine example of what a man can do and be by years of simple, honorable, useful living.

CHARLES W. SHERMAN
WILLIAM P. MELLEY

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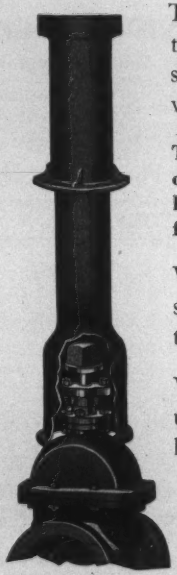

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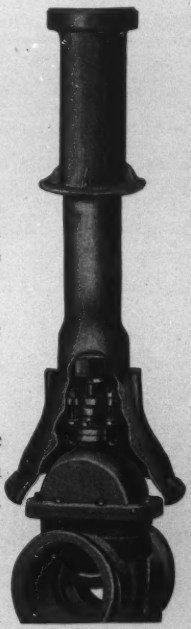

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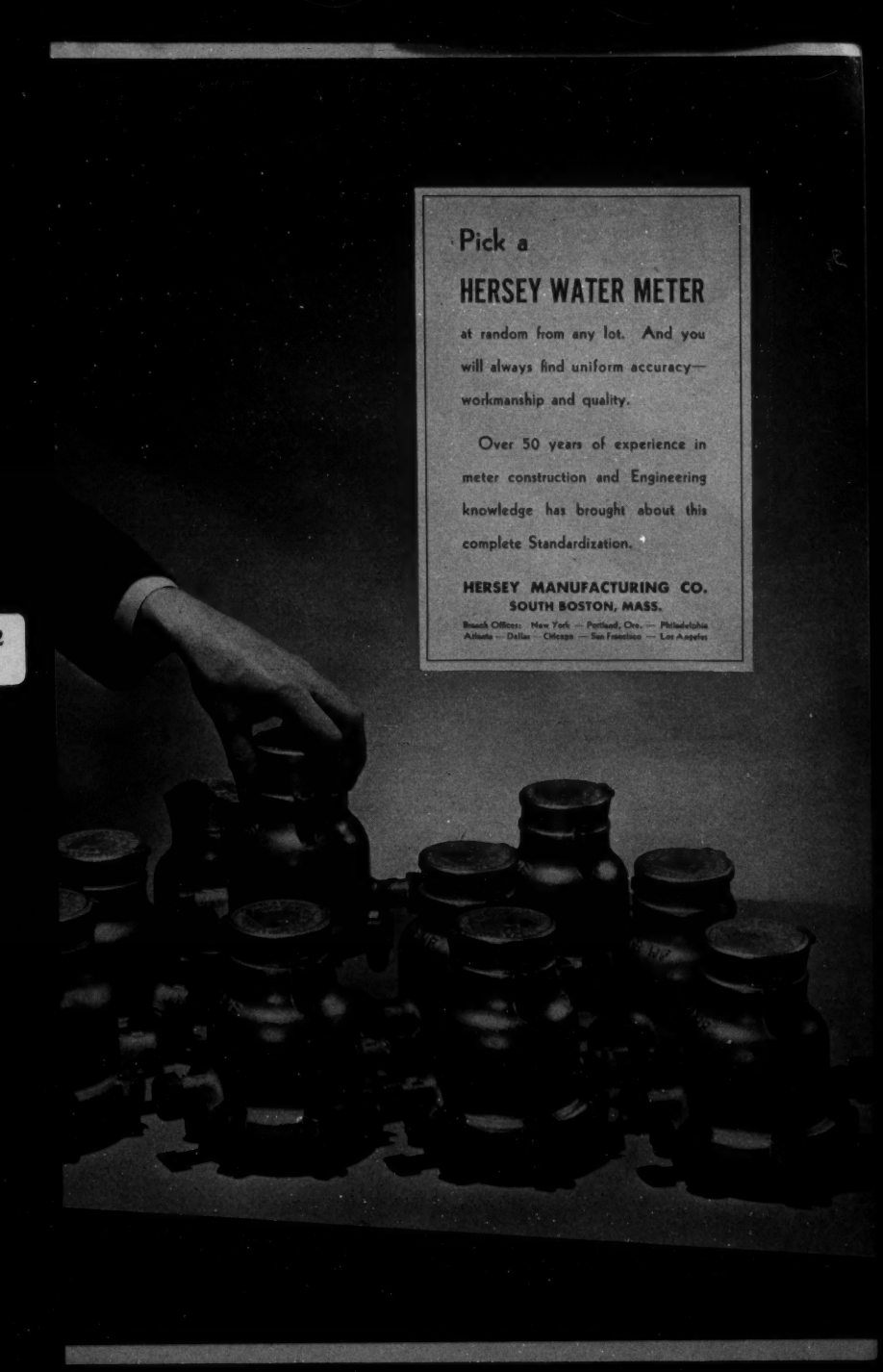
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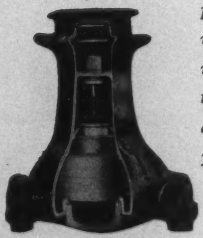

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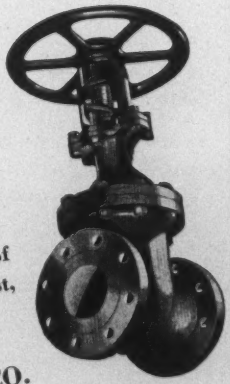

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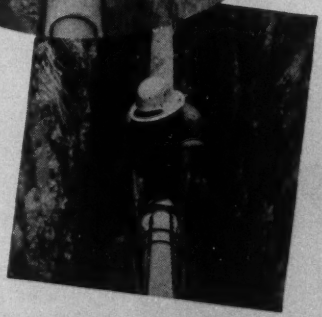

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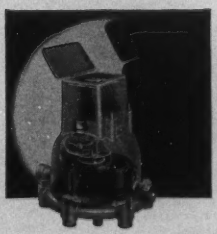

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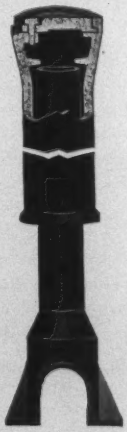

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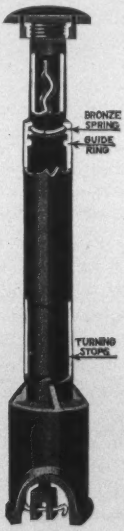

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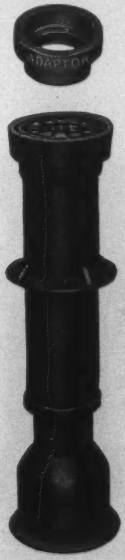

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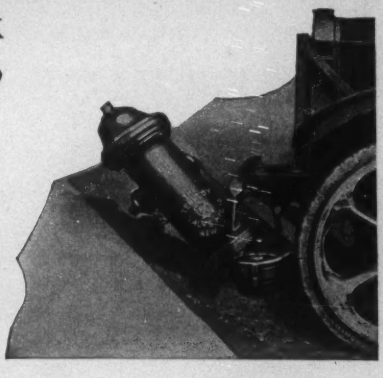


Send for Bulletins

IN NO INSTANCE—either on demonstration test or in accidental collisions, has the Safety Breakable Section ever failed in its function of preventing breakage of the major and expensive parts of the SAFETOP. The only parts that need be replaced after breakage are a threaded standpipe ring and a stem coupling. These parts cost $6.00—a very small fraction of the cost of the complete hydrant which must ordinarily be replaced after breakage from accidental collision. Repairs do not necessitate shutting off the water pressure, and can be completed within half an hour.

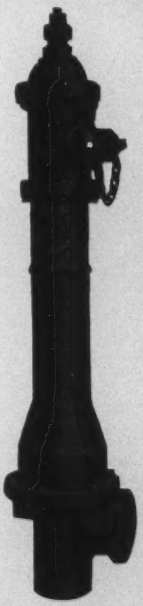
In addition to its unique safety feature, the Kennedy SAFETOP Fire Hydrant assures quick response with full main pressure delivered at the nozzle in fire service; and its simple operating mechanism and wear-resisting valve facings last indefinitely. Write for bulletins describing its many special features.

The Kennedy Valve Mfg. Co., Elmira, N. Y.

KENNEDY
SAFETOP FIRE HYDRANT
REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants



Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced. . . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

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LEAD PIPE

Used by leading WATER WORKS for over 50 years. If proper weight is used, combined with good workmanship, your FINAL COST is assured, as REPAIRS are unnecessary. LEAD PIPE is sufficiently ductile to conform to any sagging condition. There is no RUSTING of pipe or joints; no DISCOLORATION of water.

LEAD WOOL

Every Atom Pure Lead

For calking pipe joints under the most difficult conditions; for overhead joints or in wet places where the use of molten lead is not only impracticable but dangerous — LEAD WOOL may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe, without danger of leaks.

Compared with the poured joint, in this respect, the superiority of LEAD WOOL is apparent.

LEAD PIPE TIN-LINED LEAD PIPE
PURE BLOCK TIN PIPE SOLDER
DUTCH BOY WHITE LEAD & RED LEAD

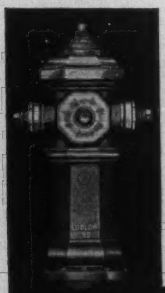
Highest Quality Soft Virgin Omaha Pig Lead

National-Boston Lead Co.

800 Albany St. Boston, Mass.

Check LUDLOW Hydrants

Check these points about the Ludlow No. 90 hydrant—



- √ Full force — no obstruction in waterway
- √ Non-freezing—drains from bottom.
- √ Surge and water hammer eliminated.
- √ Replaceable without digging.
- √ Parts easily removable — low maintenance.

—and finally, the most modern, graceful design obtainable. Send for free folder.

The LUDLOW VALVE MFG. CO.
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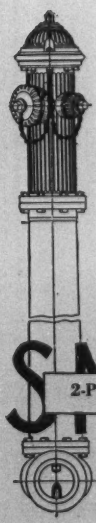


Minimum Trouble and Expense When Breaks Come

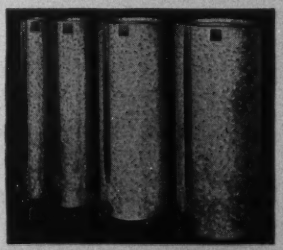
THE Smith Two-Part Standpipe Hydrant was designed to make the expense as small as possible when there is a break as the result, for instance, of careless auto truck driving.

The upper section will always break first. It can easily be renewed. And of course there can be no leakage of water because the main valve is of the compression type.

SMITH
2-Part Standpipe Hydrant

THE A. P. SMITH MFG. COMPANY
East Orange, N. J.

Ford Calibrated TESTING TANKS



These tanks are made in four sizes. They are heavily galvanized and provided with percentage calibration, gauge glass and quick-opening drain valve. Simple and easy to use. Hundreds in use. Write for information.

The Ford Meter Box Co.
WABASH, INDIANA

HAYS begins at the MAIN

Since 1869 Hays has built to the exacting requirements of the Water Works Industry. Tap the Main with a Hays Tapping Machine and follow through with dependable Hays Service Fittings for iron pipe, lead or copper. Hays Corporation Stops and Curb Stops are made in all styles and sizes. Write for Catalog.

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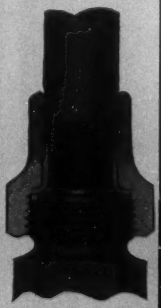
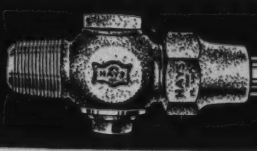
This type of joint was designed to meet the specific requirements of certain Water Departments and is available directly on all styles of Hays Copper Service fittings.

HAYS DOUBLE SEAL JOINT

This joint features a 2-faced pipe flare (45° + 90°) and a 2-faced machined seal (45° + 90°) which is by test the strongest flanged connection available. Available by Adapter on any Corporation Stop and directly on more than 400 styles and sizes of Hays Service and Plumbing fittings.



USE THE HAYS COPPER SERVICE METHOD



Hays Adapts Copper to meet any Requirements

As a pioneer in the development of copper pipe services, Hays has popularized its use by making it easily adaptable to meet existing line equipment economically. Every community can have the advantage that copper pipe makes possible from Main to Curb to House with the Hays Copper Service Method. Let us have your problem.

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BATH FIXTURES
COPPER PLUMBING
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This Man Tests Water By Unusual Sense Of Smell
WATER SMELLER STARTS SURVEY
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Water Smeller
He Tests Water by Sense of Smell
WATER SMELLER NAMED FOR CITY
BAD WATER PLAYED TO DISTRACTION

This demonstrates the value of publicity created for the purpose of arousing the interest of Mr. John Public in the important functions of water departments.

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Each pump is designed to handle 3 million gallons of water per day against a total dynamic head of 162 feet.

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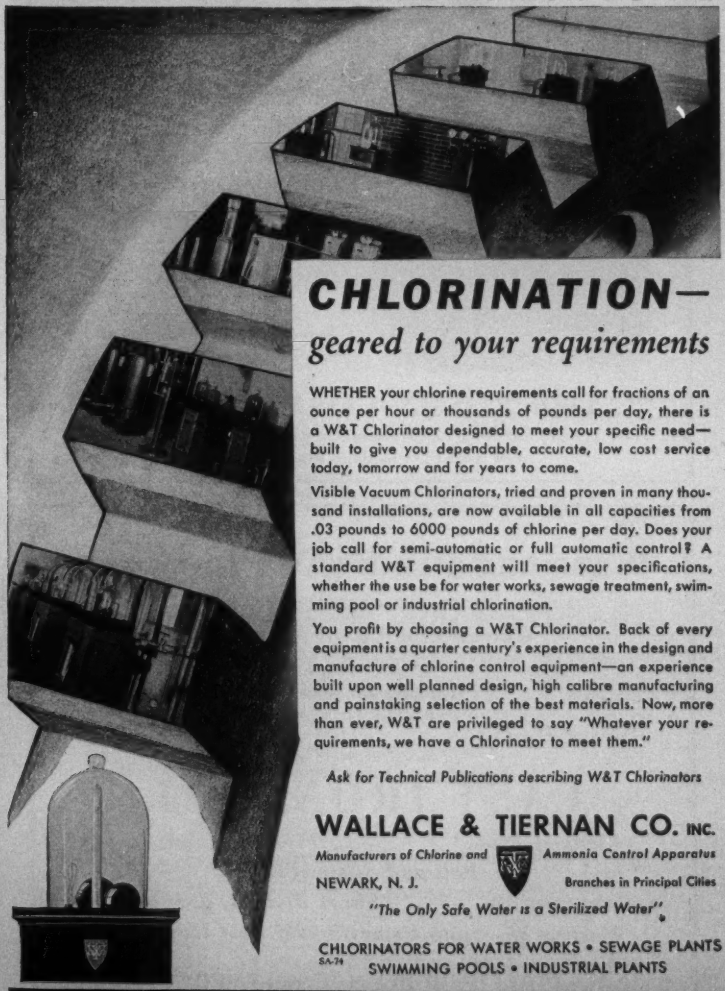

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Visible Vacuum Chlorinators, tried and proven in many thousand installations, are now available in all capacities from .03 pounds to 6000 pounds of chlorine per day. Does your job call for semi-automatic or full automatic control? A standard W&T equipment will meet your specifications, whether the use be for water works, sewage treatment, swimming pool or industrial chlorination.

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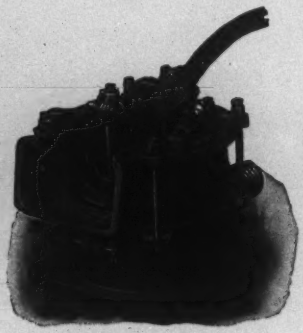

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REG. U.S. PAT. OFF.

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Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

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Standpipe can be revolved quarter turns — Nozzles always in right direction.

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X. Henry Goodnough, Inc.
Engineers

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Needham, as well as many other New England municipalities equipped by Fairbanks-Morse, is showing a substantial saving in operating costs. Get the facts on F-M power and pumping equipment by writing to Fairbanks, Morse & Co., 178 Atlantic Avenue, Boston, Mass.

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To settle high bill complaints

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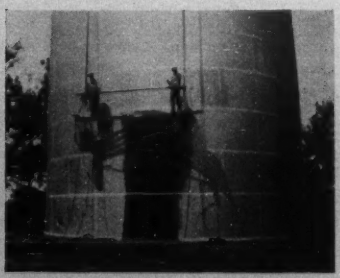

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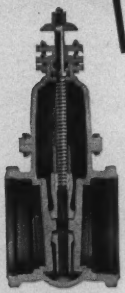
And a Wood Valve will do it Surely



Deep under ground—buried for years—gate valves may be neglected but they must work when the emergency comes.

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Send specifications for prices. Be ready to "cut that water fast."

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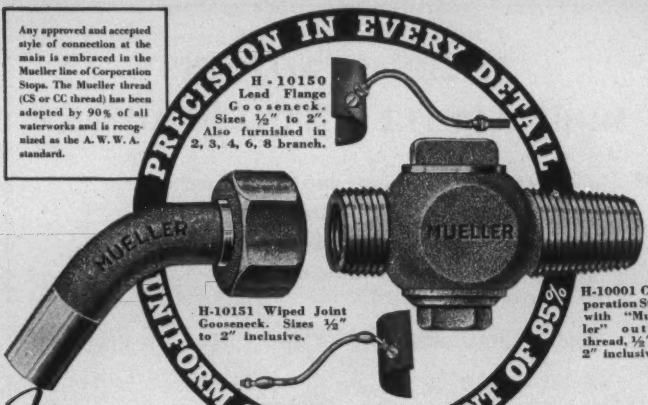

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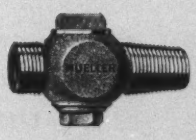

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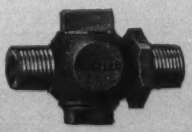

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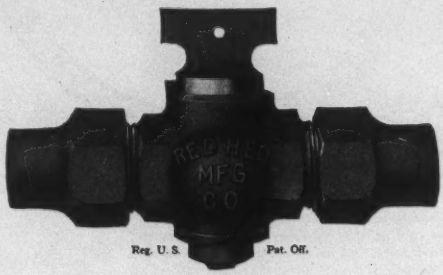

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